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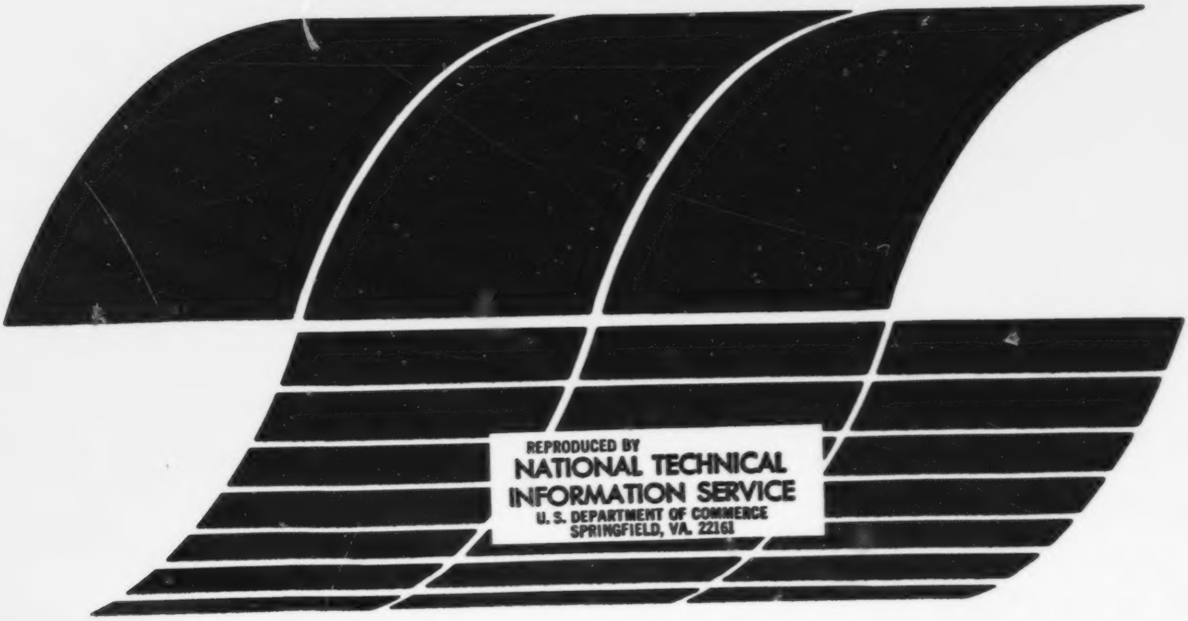

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The report gives results of a Source Test and Evaluation Program at a commercial coal gasification plant using a Wellman-Galusha gasifier to produce low-Btu fuel gas from anthracite coal. Major objective of the tests was to perform an environmental assessment of the plant's waste streams and fugitive emissions. Results of the chemical analyses of the plant's waste streams indicated that all contained organic and/or inorganic components which may have potentially harmful health and/or ecological effects. In the pokehole and coal hopper gaseous emissions, CO, NH_3, and possibly $Fe(CO)_5$ were found to be of major concern. Organic compounds which were not specifically identified were of potential concern in the ash sluice water. The gasifier ash and cyclone dust contained a number of trace elements and possibly organics that may be potentially harmful. Analyses of the leachate from these two solid waste streams indicated that the leachate may have potentially harmful health and/or ecological effects; however, at a substantially lower level of concern when compared with the results of the ash and dust themselves. Overall, the indicated potential health and ecological effects of the plant's waste streams were found to be significantly lower than those for waste streams produced by gasifying bituminous coals.

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i.a

ABSTRACT

This report presents the results of a Source Test and Evaluation Program conducted at a commercial coal gasification facility. The facility uses a Wellman-Galusha gasifier to produce low-Btu fuel gas from anthracite coal. The major objective of the test program was to perform an environmental assessment on the facility's waste streams and fugitive emissions. Additional objectives were to characterize the product gas cyclone's particulate removal efficiency and to characterize the flue gas resulting from the combustion of the low-Btu product gas. Results from the chemical analyses of the plant's waste streams indicated that all waste streams contain organic and/or inorganic components which may have potentially harmful health and/or ecological effects. In the pokehole and coal hopper gaseous emissions, CO, NH_3 and possibly $Fe(CO)_5$ were found to be of major concern. Unidentified organics were of potential concern in the ash sluice water. The gasifier ash and cyclone dust contained a number of trace elements and possibly organics that may be potentially harmful. Analyses performed on the leachate from these two solid waste streams indicated the leachate may have potentially harmful health and/or ecological effects; however, at a substantially lower level of concern when compared to the results of the ash and dust themselves.

Overall, the indicated potential health and ecological effects of the Wellman-Galusha facility's waste streams were found to be significantly lower than those for waste streams produced by gasifying bituminous coal. This was due principally to the much lower levels of organics in the Wellman-Galusha facility's waste streams. The results of bioassay screening tests also indicated lower potential effects of the facility's waste streams.

As part of the test program, on-line instrumentation to monitor gaseous species (H_2S, COS, CS_2, SO_2, NH_3, and C_1 - C_6 hydrocarbons) was developed. The results from the on-line instrumentation were validated by alternate sampling and analysis techniques.

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SECTION 1.0

INTRODUCTION

Radian Corporation of Austin, Texas, under contract to the Environmental Protection Agency (EPA), is performing a comprehensive environmental assessment of low-Btu gasification technology. A major portion of this assessment involves Source Test and Evaluation (STE) programs at operating low-Btu gasification facilities. The ultimate objective of each STE program is to gather the data necessary for evaluating: (1) environmental and health effects of multimedia waste streams from low-Btu gasification facilities, and (2) equipment required for controlling problem waste streams.

1.1 PROGRAM SUMMARY

The Wellman-Galusha gasification system is one of only two types of coal gasifiers currently in commercial use in the U.S. At the York, PA. plant of the Glen-Gery Brick Co., a Wellman-Galusha gasification system is used to convert anthracite coal into a low-Btu gas which is then used as a fuel for a brick kiln. To obtain environmental assessment data on this type of gasification facility, Radian conducted a source test and evaluation program at the York plant. The results, conclusions, and recommendations derived from that test program are presented in this report.

In the Wellman-Galusha gasifier, coal is reacted with steam and oxygen (air) in a single-stage, fixed bed, atmospheric pressure vessel. At the Wellman-Galusha facility tested, the raw, low-Btu gas from the gasifier is treated in a hot cyclone to remove large particulates before combusting the gas in a brick kiln.

The Glen-Gery facility was selected for the STE program for several reasons, including:

- It is a commercially operating gasifier typical of those currently in use in the U.S.
- It affords an opportunity to make a significant contribution to the low-Btu gasification technology

data base for systems using anthracite. Systems using anthracite also produce a raw product gas that is essentially tar and oil free. This feature simplifies the task of obtaining representative process and waste stream samples for environmental characterization.

- It is part of the U.S. Department of Energy's (DOE's) Gasifiers in Industry Program, and as a result includes special instrumentation that facilitates the collection of both process and environmental data.

The specific objectives of the STE program conducted at the Glen-Gery Wellman-Galusha facility were to:

- perform an environmental assessment of the waste streams from the gasification system,
- characterize the particulate removal performance of the product gas cyclone, and
- characterize the flue gas resulting from the combustion of the low-Btu product gas.

Overall results from the chemical analyses indicate that all waste streams may contain potentially harmful components. However, the potential effects indicated for these streams are much lower than those found for waste streams produced by gasifying bituminous coal (Ref. 1). This is due principally to the low concentrations of organics in the Glen-Gery plant waste streams. The results of biological screening tests confirm that the potential effects of the plant's waste streams are low.

In order to characterize the particulate removal efficiency of the cyclone the particulate concentrations in the product gas stream were measured before and after the cyclone. Although problems were encountered in performing the tests (see Section 1.2.2.) the particulate removal efficiency was calculated to be (65 ± 20)%.

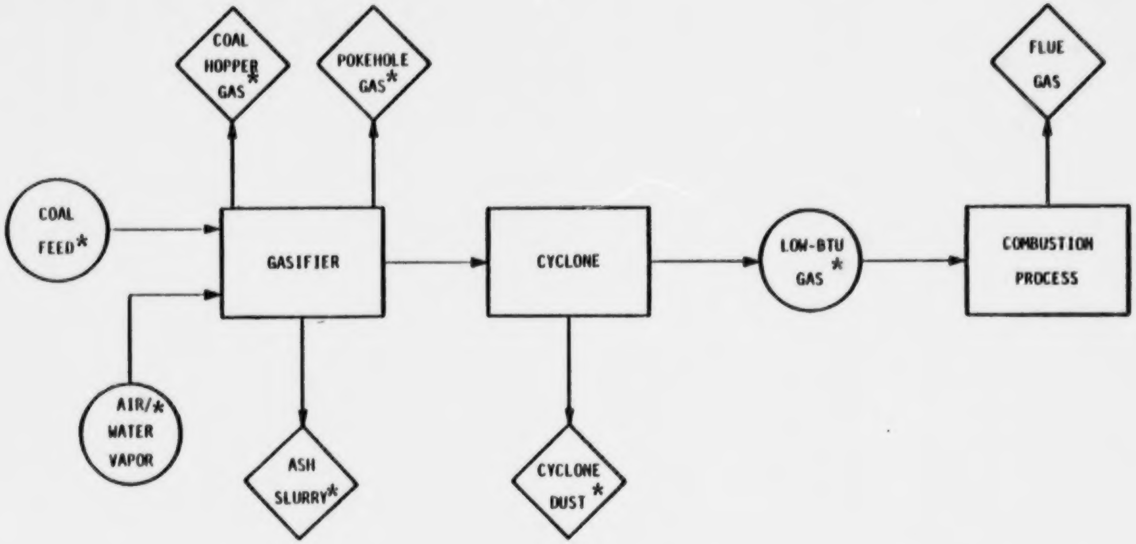
A significant problem was also encountered in characterizing the low-Btu gas combustion products. Since flue gases from the brick kiln also contained natural gas combustion products, a small test burner constructed of bricks was used for sampling the low-Btu gas combustion products. Unfortunately, air leakage through cracks in the brick structure of the test burner caused extremely high levels of excess air in the flue gas. The effect of this on the destruction of organics present in the low-Btu fuel gas or the formation of NO_x could not be ascertained.

1.1.1 Plant Description

The Wellman-Galusha facility tested by Radian produces a low-Btu gas which is used, along with natural gas, as fuel for a brick kiln. Two Wellman-Galusha gasifiers are installed at the test site. During the sampling effort, however, only the gasifier which was recently installed as part of the DOE's Gasifiers in Industry Program was being operated. A block flow diagram of the Glen-Gery gasification facility is given in Figure 1-1. Also shown are the major waste streams from the facility.

Three process operations are used at the Glen-Gery gasification facility: coal preparation, gasification, and gas purification. The specific functions performed in each process operation are summarized below:

- Coal Preparation - consists of delivery and storage of presized anthracite coal, along with conveying and storing this coal in the gasifier feed hopper.
- Gasification - consists of producing raw, low-Btu gas from anthracite coal using fixed-bed, single stage, atmospheric pressure Wellman-Galusha gasifiers. The coal feed enters the top of the gasifier through four coal pipes. A lock hopper arrangement in the coal hopper is used to refill the coal pipes. The coal is reacted with steam and oxygen (air) to produce the low-Btu gas. Ash is removed from the gasifier through a rotating grate and collects in a hopper beneath the grate. Periodically water is added to the ash hopper to aid in removing the ash. Pokeholes located on top of the gasifier are opened periodically to permit the insertion of rods used to measure the position and depth of the ash and fire zones.
- Gas Purification - consists of a refractory brick-lined cyclone for removal of particulate matter from the hot, low-Btu gas. The removed particulates collect in the bottom of the cyclone and are periodically discharged through a slide valve.


COAL FEED*
AIR/* WATER VAPOR
COAL HOPPER GAS*
POKEHOLE GAS*
GASIFIER
ASH SLURRY*
CYCLONE
CYCLONE DUST*
LOW-BTU GAS*
COMBUSTION PROCESS
FLUE GAS

70-1483-2

* Streams sampled during the Source Test and Evaluation Program

Figure 1-1. Schematic Flow Diagram of the Glen-Gery Wellman-Galusha Low-Btu Gasification Facility

1.1.2 Test Program Description

In order to meet the objectives of this STE program samples of twelve process and waste streams were obtained, as well as flow rate data and data for a number of operating parameters. This information was used to:

- calculate a mass balance for the facility,
- characterize the facility's waste streams (including the low-Btu gas combustion products), and
- characterize the collection efficiency of the product gas cyclone.

Mass Balance Determinations

During a 96-hour period of the test program, flow rate measurements were determined for the following:

- coal feedstock,
- inlet air,
- water vapor in the inlet air,
- gasifier ash,
- coal hopper gases,
- pokehole gases,
- cyclone dust, and
- product low-Btu gas.

A mass balance around the facility was calculated from these determinations.

Waste Stream Characterizations

The waste streams from the Glen-Gery gasification facility are listed in Table 1-1. The streams sampled by Radian are indicated with an asterisk. Criteria for selection of streams for sampling included accessibility, plant operation, and potential for pollution. For example, flue gases from the brick kiln were not sampled because natural gas combustion products were also present. Instead, the low-Btu gas combustion products were sampled using a test burner.

TABLE 1-1. MULTIMEDIA WASTE STREAMS AT THE GLEN-GERY WELLMAN-GALUSHA GASIFICATION FACILITY

Gaseous Emissions
- Coal hopper gases*
- Pokehole gases*
- Brick kiln flue gases
- Cooling tower emissions

Liquid Effluents
- Ash sluice waste*

Solid Wastes
- Gasifier ash*
- Cyclone dust*

---

* Indicates the waste streams sampled during the test program.

Cyclone Particulate Removal Efficiency Study

Determining the particulate removal efficiency of the hot cyclone was one objective of the STE program. In order to achieve this objective, particulate concentrations were measured in the product gas stream before and after the cyclone. From these data, the particulate removal efficiency of the cyclone was determined.

1.2 SOURCE TEST EVALUATION SUMMARY

The results and conclusions from the source test and evaluation program at the Glen-Gery gasification facility are summarized for the following areas:

- environmental assessment,
    - mass balance
    - steam characterization
- cyclone efficiency tests, and
- test burner flue gas characterization.

1.2.1 Environmental Assessment

A complete assessment of the environmental aspects of a process requires knowledge about both the compositions and flow rates of multimedia waste streams.

Flow Rates

The flow rates of the major inlet and outlet streams from the Glen-Gery facility were monitored over a 96-hour period. The gasification facility operated at full capacity during this time except for a 7-hour upset caused by a mechanical failure. Table 1-2 presents average flows with associated confidence intervals for each major stream. The confidence intervals were calculated from multiple measurements of the flow rate, if possible. Otherwise they are estimated from knowledge of the measurement technique reliability, variability of gasifier operation and the experience of the sampling crew.

A total mass balance based on these flow rates is presented in Table 1-2. Closure of the balance within the combined confidence intervals of the individual stream flow rates indicates that there are no significant uncertainties in the flow data. This conclusion is supported by material balances for C, H, N, O, and S which are presented in Section 2.3. However, a mass balance for ash materials, also presented in Section 2.3, indicates that the gasifier ash flow rate is low and should be in the range of 140 kg/hr (300 lb/hr).

The energy conversion efficiency of the process, calculated from the coal heating value and flow rate and product gas composition and flow rate, is (101 ± 16)%. The expected range of 85 to 90% for this type of process is included in the confidence interval of this result.

TABLE 1-2. PROCESS STREAM FLOW RATES FOR THE GLEN-GERY GASIFICATION FACILITY

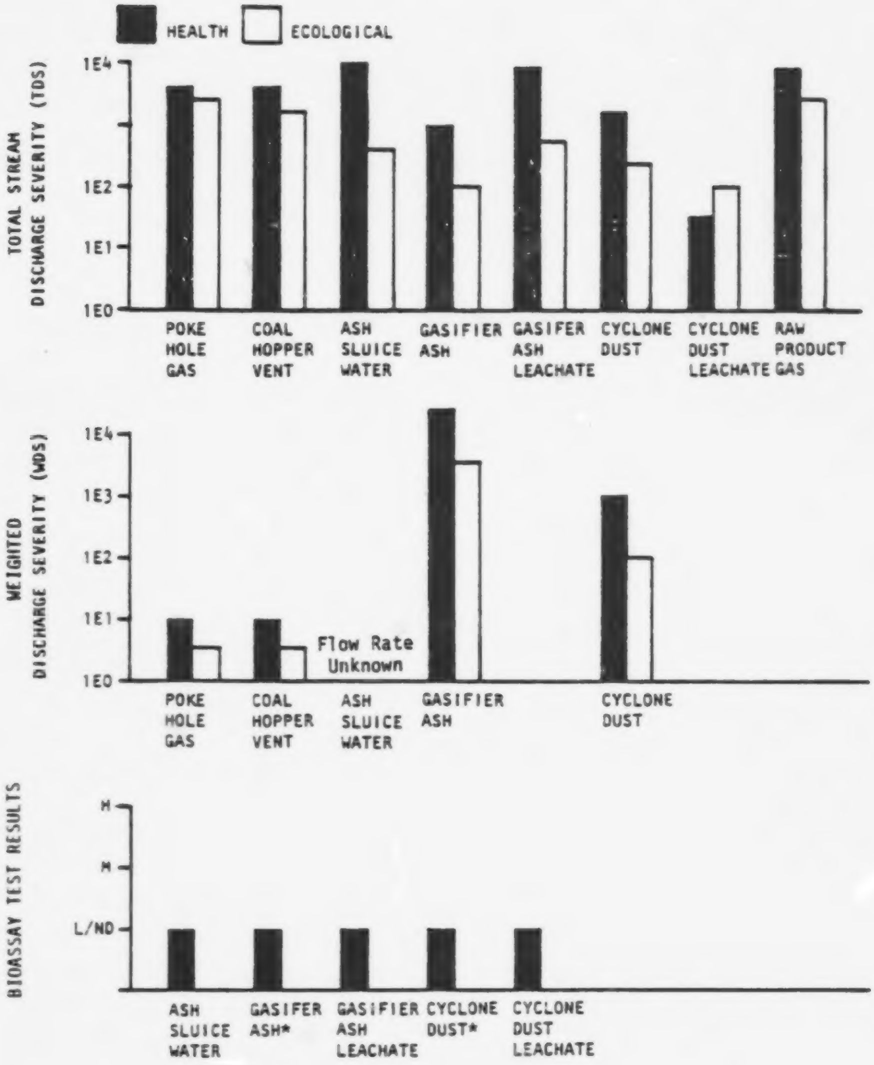
Input Streams	Flow Rate kg/hr (lb/hr)	Confidence Interval ± 2σ
Coal Feed	790 (1700)	± 10%
Inlet Air	3570 (7870)	± 7.5%
Water Vapor with Inlet Air	700 (1500)	± 15%
Total Input	5060 ± 300 (11,100 ± 660)	
Output Streams		
Gasifier Ash	74 (160)	± 60%
Cyclone Dust	0.7 (1.5)	± 30%
Coal Hopper Gas	8 (18)	± 50%
Pokehole Gas	6 (13)	± 100%
Product Gas	4800 (10,600)	± 11%
Total Output	4900 ± 530 (10,800 ± 1170)	

Waste Stream Characterization

Figure 1-2 summarizes the SAM/1A evaluation and bioassay test results for the multimedia waste streams sampled. All of the waste streams were found to contain constituents in potentially harmful concentrations. While greater than one, the total discharge severities (TDS) shown are generally significantly less than those calculated for similar waste streams from a gasification facility using bituminous coal (Ref. 1). The low potential for harmful effects associated with Glen-Gery waste streams is also supported by the results of the bioassay screening tests.

The following text contains a summary of the multimedia waste stream characteristics and control strategy recommendations. Unidentified organic materials in the process effluents are included in the calculations of discharge severity (DS) by assuming the worst case. These worst case results indicate specific potentially harmful organic compounds or classes for which specific analysis should be made in any future work.

Gaseous Waste Streams - The gaseous waste streams sampled



*ASH MORE TOXIC THAN CYCLONE DUST IN THE SOIL MICROCOSM TEST

H: High Effects
M: Moderate Effects
L/ND: Low or Nondetectable Effects

Figure 1-2. Total Stream, Weighted Discharge Severities and Bioassay Test Results for the Glen-Gery Wellman-Galusha Waste Streams.

at the Glen-Gery facility were the pokehole gas and the coal hopper gas. Bioassay tests were not performed on either of these streams.

The SAM/1A evaluation of the chemical analyses for these streams is summarized in Table 1-3. The pokehole gas flow rate was too low to provide an adequate quantity of sample for analysis. Therefore, its composition was assumed to be the volatile (b.p. < 100°C) fraction of the raw product gas. For both streams CO is the major contributor to the total stream discharge severity (TDS).

TABLE 1-3. GASEOUS WASTE STREAM RESULTS SUMMARY

Discharge Severity Range	Compounds Found from Chemical Analysis	
	Health	Ecological
Pokehole Gas		
10^3-10^4	CO	CO
10^2-10^3	-	NH_3
10-10^2	As, CO_2, H_2S	-
1-10	CH_4, NH_3, HCN Li, Ni, SO_2	HCN
Coal Hopper Gas		
10^3-10^4	CO	CO
10^2- 10^3	$Fe(CO)_5$	-
10-10^2	H_2S	-
1-10	CH_4, CO_2	-

The low flow rate of the pokehole gas reduces its potential hazardous effects. The flow rate, and therefore, the potential effects, could be further reduced with better seals or better maintenance of the seals on the pokeholes. If further control of this stream is necessary, injection of an inert gas into the pokehole during the poking operation could be employed. Also, good ventilation of the pokehole area would help reduce worker exposure.

Although the SAM/1A evaluation of the coal hopper gas indicates a potential hazard, the low flow rate of this stream greatly reduces its potential effects. Collecting and venting the gas to the gasifier inlet air or dispersing the gas in the ambient air are the recommended control techniques. Since the coal hopper rarely requires manual attention, workers can be kept out of the area to prevent exposure to the potentially hazardous gases.

Liquid Waste Streams - The ash sluice water was the only liquid waste stream sampled from the Glen-Gery facility. Trace element, water quality, and organic analyses as well as bioassay tests for health effects were performed on this sample.

Less than 0.1% of the organic extractables were identified by GC/MS. Of the compounds identified, only phthalate esters were found in concentrations which gave DS values greater than one. The mass of unidentified extractable organics was assumed to consist entirely of compounds having the highest DS values and the TDS was calculated using this worst case assumption. The SAM/1A analysis and the bioassay test results for the ash sluice water are summarized in Table 1-4.

TABLE 1-4. SUMMARY OF CHEMICAL AND BIOASSAY TEST RESULTS FOR ASH SLUICE WATER

Discharge Severity Range	Compounds Found From Chemical Analysis Health	 Ecological	Bioassay Test Results	
10^4-10^5	Fused Polycyclic Hydrocarbons[a]	-	Health Ames	Negative
10^3-10^4	-	-	WI-38 (EC_{50})	>600 µl/ml of culture
10^2-10^3	-	Alkenes, Cyclic Alkenes, Dienes, Nitrophenols[a]	Rodent Acute Toxicity (LD_{50})	>10 g/kg rat
10-10^2	-	Fe, Ti		
1-10	Ba, Cr, Fe, La, Li	Phthalate esters, Ba, Cd, Cr, Cu, HCN, Li, Ni, V		

[a] These categories of organic compounds contain the compounds which provide the largest discharge severity for the unidentified organics based on TCO + GRAV in the sluice water (~50,000 µg/ℓ). The worst case compounds corresponding to the categories are listed below.

Category	Compound
Fused Polycyclic Hydrocarbons	7,12 Dimethylbenz(a)anthracene
Alkenes, Cyclic Alkenes, Dienes	Dicyclopentadiene
Nitrophenols	Dinitrophenols

The SAM/1A evaluation indicates that the ash sluice water could have potential harmful effects. Also, TSS, BOD, PO_4^{-3} and CN^- exceed the most stringent water effluent standards (see Table 5-19 for the basis of the most stringent standards). Although bioassay tests indicate a low potential for harmful health effects, it is recommended that bioassay tests be conducted to determine the potential ecological effects of the ash sluice water. Qualitative organic analysis for the worst case categories is also recommended to characterize the unidentified organics.

The potential harmful effects of the ash sluice water could be essentially eliminated by separating it from the ash slurry and reusing it the next time ash is removed. Recycling would of course increase the concentration of dissolved components in the sluice water. However, because the dissolved species come from the ash, their concentrations would not increase to the point of solids precipitation. Thus, there would be no need for a blowdown stream. A disadvantage of recycling the sluice water is that the water that remains with the ash will also contain increased concentrations of dissolved components. Whether this poses a greater harmful effect than discharging the "once through" ash sluice water would need to be determined on an individual case basis.

Solid Waste Streams - Two solid waste streams were sampled at the Glen-Gery facility: gasifier ash and cyclone dust. Leaching tests were performed on both solid samples. The solid samples and their leachates were analyzed for organics and trace elements as well as biological activity. The leachates were also analyzed for water quality parameters.

A) *Gasifier Ash* - The GC/MS analysis of the gasifier ash showed that the major extractable component was elemental sulfur. Approximately 1% of the extractable mass was identified as phthalate esters. Only a small amount of extractable material was unidentified by GC/MS. This quantity was assumed to be composed of compounds with the lowest discharge multimedia environmental goal (DMEG) values. The results of the SAM/1A analysis of the gasifier ash are summarized in Table 1-5. The identified inorganics dominate the TDS results.

Also summarized in Table 1-5 are the results of the bioassay screening tests for the gasifier ash. The health based bioassay tests indicate a low potential for harmful effects.

TABLE 1-5. SUMMARY OF CHEMICAL AND BIOASSAY TEST RESULTS FOR DRY GASIFIER ASH AND LEACHATE

Discharge Severity Range	Compounds Found from Chemical Analysis: Health	Compounds Found from Chemical Analysis: Ecological	Bioassay Test Results	
Dry Gasifier Ash				
10^3-10^4	-	-	Health	
10^2-10^3	Ba, Cr, Fe, Li, Mn, Ni	-	Ames RAM (EC_{50})	Negative >1000 µg/ml of culture
10-10^2	Fused Polycyclic Hydrocarbons[a], Be, Co, Cu, Pb, Se, Th, V, Zr	Cu, Fe, Ni	Rodent Acute Toxicity (LD_{50})	>10 g/kg rat
1-10	Al, As, Bi, Cd, Ca, Hf, Mg, Si, Ag, Sr, Ti, Y	Alkenes, Cyclic Alkenes and Dienes, Aromatic Amines and Diamines, Ring Substituted Aromatics, Nitrophenols[a], Phthalate esters, Al, Ba, Cd, Cr, Pb, Li, Mn, Ti, V	Ecological Soil Microcosm	*
Ash Leachate				
10^3-10^4	Fused Polycyclic Hydrocarbons[a]	-	Health Ames	 Negative
10^2-10^3	-	Alkenes, Cyclic Alkenes, Dienes, Aromatic Amines, Diamines, and Nitrophenols[a]	WI-38 (EC_{50}) Rodent Acute Toxicity (LD_{50})	>600 µl/ml of culture >10 g/kg rat
10-10^2	-	Phthalate Esters, Zn		
1-10	-	Cd, Ag		

* The soil microcosm test results cannot be interpreted in terms of a high, medium, or low potential for hazard but comparatively, the gasifier ash was clearly more toxic than the cyclone dust.

[a] These categories of organic compounds contain the compounds which provide the largest discharge severity for the unidentified organics based on TCO + GRAV in the ash (~40 µg/g) and in the ash leachate (~40,000 µg/l). The worst case compounds corresponding to the categories are listed below:

Category	Compound
Fused Polycyclic Hydrocarbons	7,12 Dimethylbenz(a)anthracene
Alkenes, Cyclic Alkenes, Dienes	Dicyclopentadiene
Nitrophenols	Dinitrophenols

The only ecological bioassay test conducted on the gasifier ash was the soil microcosm test. While the results from this test cannot be interpreted in terms of low, medium, or high potential effects, the test did show that the gasifier ash was clearly more toxic than the cyclone dust.

The extractable material from the ash leachate was also analyzed by GC/MS. Like the ash sluice water analysis, very little of the material extracted was chromatographable on the GC/MS system. Phthalate esters were identified. The amount of extractables indicated by the TCO and GRAV screening analysis was assumed to be the worst case compounds. The inorganic elements in the leachate contribute little to the potential effect compared to the worst case organics (See Table 1-5). Also, trace element concentrations in the leachate were within the Resource Conservation and Recovery Act (RCRA) standards and bioassay tests on both the ash and ash leachate indicate a low potential for harmful health effects. However, specific analysis of the ash and ash leachate to determine the organics unidentified by GC/MS is recommended to obtain a more accurate indication of the total discharge severity. Also, bioassay tests should be conducted to determine the potential ecological effects of the ash and ash leachate.

B) Cyclone Dust - Approximately 20% of the material extracted from the cyclone dust was identified by GC/MS analysis. The majority of the material identified was elemental sulfur. Naphthalene, phenanthrene, fluorene and phthalate esters were identified at low concentrations. The SAM/1A evaluation of the analysis results is summarized in Table 1-6. As was the case for the gasifier ash, worst case organic DS is calculated for the amount of extractable material indicated by TCO and GRAV screening but not detected by GC/MS. The TDS is dominated by the inorganic elements identified in the cyclone dust.

The results of the bioassay tests for the cyclone dust are also presented in Table 1-6. The health based bioassay tests indicate a low potential for harmful effects. The ecological bioassay test result cannot be interpreted as a high, medium, or low potential for hazard. However, the test did show the cyclone dust was clearly less toxic than the gasifier ash.

TABLE 1-6. SUMMARY OF CHEMICAL AND BIOASSAY TEST RESULTS FOR CYCLONE DUST AND LEACHATE

Discharge Severity Range	Compounds Found from Chemical Analysis		Bioassay Test Results	
	Health	Ecological		
Cyclone Dust				
10^3-10^4	Mn	-	Health	
10^2-10^3	Fused Polycyclic Hydrocarbons[a], As, Ba, Cr, Fe, Pb, Li, Ni Se	-	Ames RAM(EC_{50}) Rodent Acute Toxicity (LD_{50})	Negative >1,000 µg/ml of culture >10 g/kg rat
10-10^2	Be, Cd, Ag, Th, V, Zn	Alkenes, Cyclic Alkenes, Dienes, Amines, Diamines, Ring Substituted Aromatics, Nitrophenols[a], Cd, Fe, Pb, Mn, Ni, Zn	Ecological Soil Microcosm	*
1-10	Al, Sb, Ca, Co, Cu, F Ca, Hf, Mg, Hg, Si, Sr, Tl, Ti, Y, Zr	Phthalate Esters, Al, Sb, As, Ba, Cr, Cu, Li, Mg, Hg, Se, Ti, V		
Cyclone Dust Leachate				
10^2-10^3	Fused Polycyclic Hydrocarbons[a]	Mn, Zn	Ames	Negative
10 -10^2	Mn	Alkenes, Cyclic Alkenes Dienes, nitrophenols,[a] Pb	WI-38 (EC_{50})	500 µℓ/ml of culture
1 -10	Pb, Li	Al, Cd, Co, Cu, Fe, Li		

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* The soil microcosm test results cannot be interpreted in terms of a high, medium or low potential for hazard.

[a] These categories of organic compounds contain the worst case compounds which provide the largest DS value for the unidentified organics in cyclone dust and cyclone dust leachate (≈5000 µg/ℓ).

The worst case compounds and their corresponding categories are listed below:

Category	Compound
Fused Polycyclic Hydrocarbons	7,12-Dimethylbenz(a)anthracene
Alkenes, Cyclic Alkenes, and Dienes	Dicyclopentadiene
Aromatic Amines and Diamines	Aminonaphthalenes
Ring Substituted Aromatics	Dibromobenzene
Nitrophenols	Dinitrophenols

The organic extractable material from the cyclone dust leachate was only subjected to GRAV and TCO determinations. The amount of extractables indicated by these analyses (unidentified organics) was evaluated using the same worst case procedures as for the ash leachate sample. The SAM/1A evaluation of the chemical test results and the bioassay test results for the cyclone dust leachate are also summarized in Table 1-6. The bioassay tests indicate a low potential for harmful health effects.

However, the fluoride concentration in the cyclone dust leachate exceeds the most stringent effluent water standards (see Table 5-19 for the basis of the most stringent standards). And, the lead concentration determined by SSMS exceeds the RCRA guidelines, which may limit the ability to landfill the cyclone dust. In that case, incineration (or use as a fuel) is a possible disposal method particularly since the cyclone dust has a heating value of 25.3 MJ/kg (10,900 Btu/lb). Combustion gases from this incineration should be analyzed for volatile elements. Quantitative lead analysis is recommended to determine if RCRA standards are actually exceeded.

1.2.2 Cyclone Efficiency

An attempt was made to determine the cyclone particulate removal efficiency by simultaneous measurement of particulate loadings in the gas entering and exiting the cyclone. The cyclone inlet sampling location did not allow collection of a representative particulate sample. There was only one and one-half duct diameters of horizontal duct from the gasifier exit to the cyclone inlet. Physical constraints allowed traversing in only the horizontal direction so the vertical stratification of particulates expected in this configuration could not be detected. Therefore, the inlet loadings measured are likely to be low. In addition, very high results for three of the five outlet particulate loading measurements indicated possible reentrainment of collected material. The two remaining sets of data indicated a removal efficiency of (65 ± 20)%. This should be considered as only a rough estimate since the inlet data are highly unreliable.

1.2.3 Test Burner Flue Gas Characterization

Since flue gases from the kiln included natural gas combustion products, a small test burner of brick construction was used to evaluate the combustion characteristics of only the product low-Btu gas. The flue gas from this burner was sampled and the resulting composition data are presented in Table 1-7. For comparison, the composition of the product low-Btu gas is also presented.

From the oxygen content of the flue gas, it is evident that the combustion was conducted with a large quantity of excess air. Using the available flow rate and composition data, the excess air was estimated from oxygen and nitrogen material balances to be approximately 400%. The effect of this high excess air on the production of NO_x and the efficiency of combustion of organics is uncertain.

The flow rates presented in Table 1-7 are based on (1) an in-line orifice meter for the product gas to the test burner and (2) velocity transverses of the combustor exhaust stack for the flue gas. Material balances for carbon across the burner do not close within the limits of the accuracy of the data and suggest that the product gas flow rate is low by as much as 50%. However, similarly calculated balances for hydrogen close within the confidence limits of the data.

TABLE 1-7. RESULTS OF LOW-BTU GAS COMBUSTION TESTS[a]

Component	Average Low-Btu Gas Concentration[b]	Average Flue Gas Concentration
Flowrate (25°C), 1atm, dry)	64.3 m^3/hr (2270 scfh)	295m^3/hr (10,400 scfh)
CO_2 (vol %)	5.5	9.5
O_2 (vol %)	0.9	10.8
N_2 (vol %)	51.6	79.7
CO (vol %)	25.5	ND
H_2 (vol %)	16.3	ND
H_2O (vol %)	5.92	5.72
C_1 (vppm)	1910 (1500-4500)[f]	0.4
C_2 (vppm)	<1	ND
C_3 (vppm)	3	ND
H_2S[c] (vppm)	630 (600-700)[f]	ND
COS[c] (vppm)	93 (70-100)[f]	ND
SO_2[c] (vppm)	21 (4-30)[f]	491
CS_2[c] (vppm)	<1 (10)[f]	ND
Total S[d] (vppm)	730[e]	199
NO_x (vppm)	NA	267
CN^- (vppm)	36[e]	<3
SCN^- (vppm)	10[e]	2
NH_3 (vppm)	180[e] (100-200)[f]	<5
$Fe(CO)_5$ (vppb)	4	17
$Ni(CO)_4$ (vppb)	10	3
Total Organics (g/m^3 @ 25°C)	6980	1910

a Approximately 400% excess air was calculated during the test.
b Based on average of product gas analyses for entire sampling period.
c Averages of gas chromatographic analyses.
d Averages of impinger collection and chemical analyses.
f Ranges for on-line gas chromatography results.

ND: Not detected.

SECTION 2.0

PLANT DESCRIPTION

The York, Pennsylvania plant of the Glen-Gery Brick Company uses both low-Btu gas and natural gas as fuels in their brick making process. The low-Btu gas is produced on-site by gasifying anthracite coal in fixed-bed, atmospheric pressure, Wellman-Galusha gasifiers. Although the York plant has operated a single Wellman-Galusha gasifier for a number of years, a second unit was recently installed as part of the DOE's Gasifiers in Industry Program. This unit, which includes special instrumentation to facilitate process data gathering, was the subject of Radian's environmental test program.

The Glen-Gery gasification facility and its multimedia discharge streams are described briefly in Section 2.1. A discussion of the plant operating mode during Radian's testing is presented in Section 2.2. Stream flow rate data obtained and the results of material and energy balance calculations are presented in Section 2.3.

2.1 PHYSICAL PLANT CONFIGURATION

The coal gasification system at Glen-Gery's York plant includes the following process operations:

- coal preparation,
- coal gasification,
- gas purification, and
- product gas utilization.

A simplified flow diagram of the gasification system is presented in Figure 2-1. A brief description of the system and its multimedia discharge streams is presented in the following subsections.

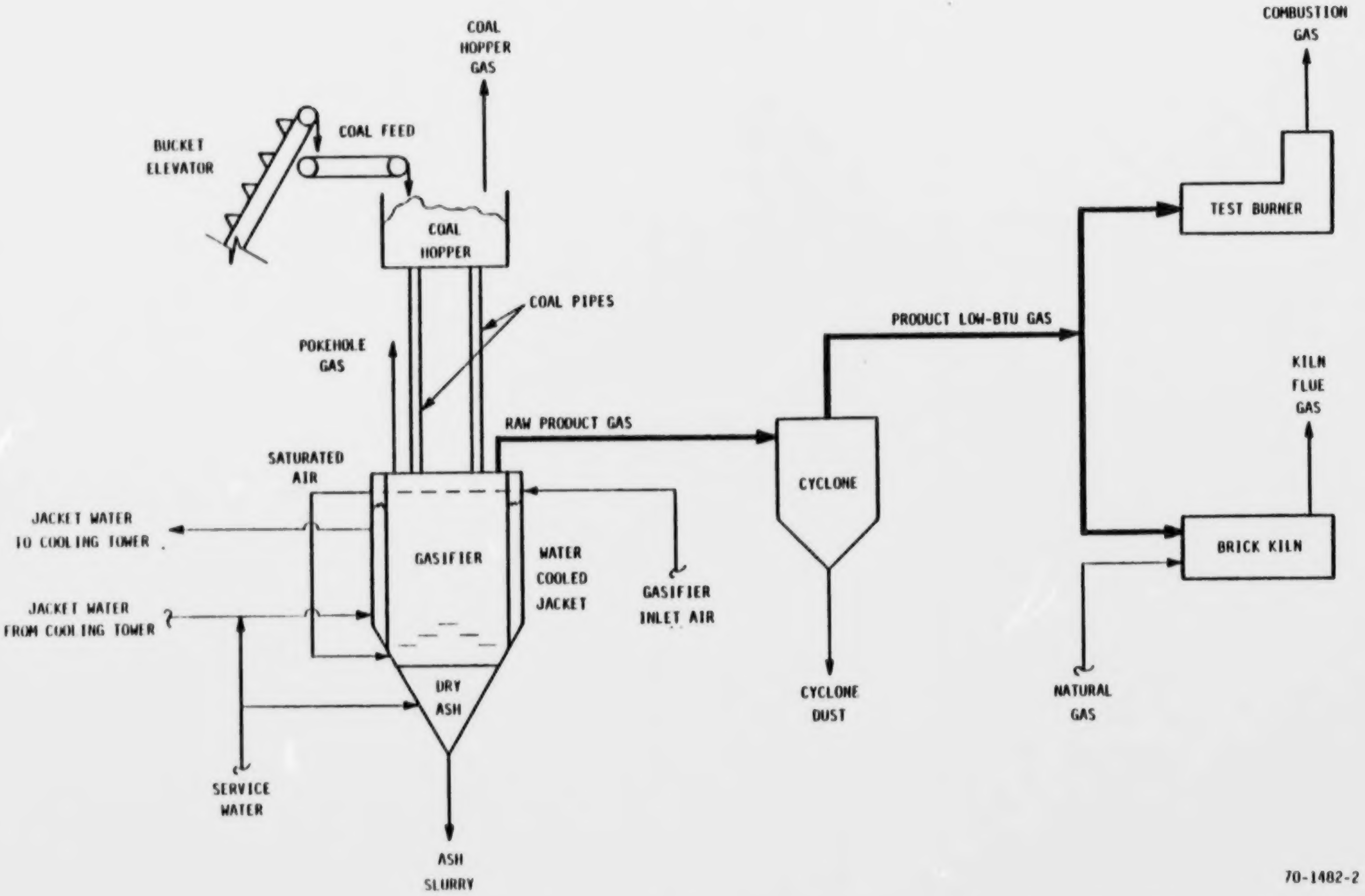

COAL HOPPER GAS
BUCKET ELEVATOR
COAL FEED
COAL HOPPER
COAL PIPES
POKEHOLE GAS
RAW PRODUCT GAS
SATURATED AIR
JACKET WATER TO COOLING TOWER
JACKET WATER FROM COOLING TOWER
GASIFIER
WATER COOLED JACKET
GASIFIER INLET AIR
DRY ASH
SERVICE WATER
ASH SLURRY
CYCLONE
CYCLONE DUST
PRODUCT LOW-BTU GAS
COMBUSTION GAS
TEST BURNER
KILN FLUE GAS
BRICK KILN
NATURAL GAS
70-1482-2

Figure 2-1. Flow Diagram for Glen-Gery Gasification Facility

2.1.1 Coal Preparation

Presized anthracite coal is received by truck and stored outside the brick warehouse in an uncovered coal receiving area. Coal is periodically moved from this area to an "active" storage pile inside the warehouse near the gasifier. At approximately 4-hour intervals, a small front-end-loader is used to feed a bucket elevator which transports the coal to a hopper atop the gasifier. A weigh belt located at the bucket elevator discharge measures the amount of coal delivered to the hopper.

The primary emission from the coal preparation operation is coal dust originating at all coal transfer points. However, due to the physical characteristics of anthracite coal, this emission is slight. In addition, water which accumulates in the bucket elevator pit helps to suppress these emissions.

2.1.2 Coal Gasification

The gasification system tested at the Glen-Gery York plant is a single-stage, fixed-bed, atmospheric pressure Wellman-Galusha gasifier. It is normally kept full of coal at all times, with four coal pipes and the lower portion of the dual compartment coal hopper providing surge capacity. About once every four hours, slide valves at the top of the coal pipes are closed, isolating the gasifier from the coal hopper. A slide valve located in the partition in the coal hopper is then opened and the lower portion of the hopper is replenished with coal.

The gasifier is both water jacketed and lined with refractory brick (bottom portion). Air, saturated with water vapor by its passage over the top of the water jacket, is introduced at the bottom of the gasifier through a grate which also supports the ash and coal beds. Ash is removed through this grate and accumulates in a hopper at the bottom of the gasifier. Ash is normally dumped from this hopper twice a day. During ash removal, water is added to the ash hopper to help seal the gasifier from the atmosphere and to slurry the ash to aid in its removal.

Raw low-Btu gas exits the top of the gasifier at approximately 400°C (750°F). Pokeholes, also located on the top of the gasifier, permit the insertion of rods used to monitor the position and depth of the "fire" and ash zones.

The emission streams associated with the coal gasification operation include:

- raw product gas which leaks past the coal hopper slide valve or which escapes with each coal feed cycle,
- ash slurry, and
- raw product gas escaping from the pokeholes during the poking operations and/or leaks from the pokeholes due to ineffective seals.

The coal hopper gases and pokehole gases are fugitive emissions which are discharged directly into the atmosphere. The gasifier ash slurry is trucked away for disposal, although a portion of the water removed with the ash collects in a sump below the gasifier.

2.1.3 Gas Purification

The gas purification operation consists of a refractory brick-lined cyclone used to remove particulates from the hot, raw low-Btu gas. Collected particulates and fugitive dust emissions, created when the cyclone dust is dumped, are the only regular discharges from this operation. The cyclone dust is disposed of with the gasifier ash.

2.1.4 Product Utilization

The low-Btu gas produced at the Glen-Gery York plant is used as fuel for a brick kiln. The major discharge stream from the kiln is the flue gas which results from the combustion of both the low-Btu gas and natural gas. The environmental aspects of low-Btu gas combustion could not be effectively evaluated by sampling the kiln flue gas. This was due to the presence of the natural gas combustion products. For this reason, a test burner was used to provide a sample of low-Btu gas combustion products.

2.1.5 Emission Stream Summary

As discussed above, emissions from the Glen-Gery York plant gasification facility include:

Gaseous Emissions

- Coal hopper gases.
- Fugitive emissions from pokeholes and other sources.
- Flue gases from the brick kiln.

Solid and Liquid Effluents

- Gasifier ash and associated sluice water.
- Cyclone dust (dry).
- Coal particulates from handling and conveying operations.

2.2 PLANT OPERATION DURING SAMPLING PERIOD

The Wellman-Galusha gasification system sampled at the Glen-Gery plant operates at full capacity (approximate coal feed rate of 900 kg/hr or 2000 lb/hr) 24 hours per day. This was true during Radian's sampling effort, except for a 7-hour period when a mechanical failure caused a temporary system shutdown.

Under normal operating procedures the coal feeding and gasifier ash and cyclone dust removal intervals are as indicated below:

- coal feeding (coal-up) - every 4 hours
- gasifier ash removal - every 12 hours
- cyclone dust removal - nominally once per week.

During Radian's testing efforts, modifications were made to the above intervals to enable various parts of the test program to be achieved. The coal-up operation was stopped for two consecutive intervals in order to enclose the coal hopper and collect samples of the coal hopper gases. The gasifier ash was removed only once per day in order to improve the accuracy of the ash flow rate determinations. In order to obtain cyclone dust flow rate data, the dust was removed at the start of the sampling effort and four days later at the end of the 96-hour material balance period. These modifications were discussed with and approved by the Glen-Gery plant manager prior to their implementation. It was also the opinion of the Glen-Gery manager that these changes would not affect the operation and/or performance of the gasification facility.

As part of the DOE's test program for the Glen-Gery gasification facility, special instrumentation was installed to facilitate process data gathering. The process data were continuously monitored and electronically transmitted to and stored in a computerized data acquisition system located on-site.

Process control instrumentation for the gasifier included an automatic adjustment for the inlet air flow rate and for the gasifier jacket cooling water recirculation rate. Set points for both of these automatic controllers were set manually. In addition, manual methods were used to control the ash removal rate, depth of the ash bed, and location of the fire zone. Total labor requirements for operating the gasification system averaged around 4 man-hours per 8 hour shift.

2.3 PROCESS FLOW RATE AND MASS BALANCE DETERMINATIONS

During the on-site testing, process data were obtained in order to determine flow rates for:

- coal feedstock,
- inlet air,
- water vapor in inlet air (after passage over the water jacket),
- gasifier ash (dry),
- coal hopper gases,

- pokehole gases,
- cyclone dust, and
- product low-Btu gas.

Most of the process data were collected over a 96-hour period during which the gasifier operated continuously except for a 7-hour upset due to a mechanical failure. The measured flow rate and analytical results from samples collected during this period have been used to calculate mass balances for total mass, ash, carbon, nitrogen, oxygen, hydrogen, and sulfur.

2.3.1 Flow Rate Measurements

The average flow rates measured during the sampling period are summarized in Table 2-1. The 95% confidence intervals stated for these flow rates are based on calculated standard deviations for the raw data, historical experience with the measurement techniques, and estimates from the experience of the field crew.

Coal is delivered to a surge hopper, located above the gasifier, via a weigh belt. The instantaneous coal flow rate data from the weigh belt were received by and stored in the on-site data acquisition system. The flow rate data were also transmitted to an integrating totalizer. Based on data from these two sources, the average coal feed rate during the test period was calculated to be 790 kg/hr (1700 lb/hr).

The inlet air rate to the gasifier was monitored continuously as part of DOE's tests. The flow rate measuring device was an anubar located in the 46 cm (18 in) diameter air duct attached to the suction side of the inlet air blower. The indicated average air flow rate was 3570 kg/hr (7870 lb/hr).

The water vapor content of the gasifier air as it enters the bottom of the gasifier was not measured directly. However, the air temperature was measured. Assuming the air is saturated by its passage over the gasifier water jacket, standard air/water psychometric charts were used to calculate the water vapor flow rate. Thus, based on the inlet air flow rate identified above (3570 kg/hr or 7870 lb/hr) and a measured inlet air temperature of 64°C (148°F), the water vapor or steam entering the gasifier was calculated at 700 kg/hr (1500 lb/hr).

TABLE 2-1. MASS FLOW RATES FOR THE GLEN-GERY WELLMAN-GALUSHA GASIFIER

Stream	Flow rate kg/hr (lb/hr)	Confidence Interval ($\pm 2\sigma$)
Coal	790 (1700)	± 10%
Inlet Air	3570 (7870)	±7.5%
Water Vapor in Inlet Air	700 (1500)	± 15%
Gasifier Ash	74 (160)	± 60%
Cyclone Dust	0.7 (1.5)	± 30%
Coal Hopper Gas	8 (18)	± 50%
Pokehole Gas	6 (13)	±100%
Product Gas	4800 (10,600)	± 11%

Gasifier ash flow rate data had to be obtained in an indirect manner and, in light of the procedures used, were subject to large inaccuracies. Normal procedures for removing gasifier ash entailed 1) adding water to the ash hopper to slurry the ash, 2) discharging the ash slurry into the bed of a truck, and 3) dumping the ash slurry in an on-site disposal area. To obtain an approximate weight of dry ash removed, the normal ash disposal procedure was modified slightly. Instead of being dumped immediately, the ash slurry was allowed to dewater for about 1 hour in the truck bed. The volume of dewatered ash was measured and a core sample was taken. The core sample was dried and weighed in order to calculate the weight of dry ash per volume of dewatered ash. Using that value, the weight of dry ash in the truck bed was calculated. The results of those calculations indicated an average dry ash flow rate of 74 kg/hr (160 lb/hr).

Raw product gas that leaks past the coal hopper slide valves is discharged directly to the atmosphere from the coal hopper. To obtain the flow rate of this stream, the top of the hopper was sealed with a sheet of polyethylene. A small sample port was installed in the enclosure and a hot wire anemometer was used to measure the gas velocity through the sample port. From these measurements, the average coal hopper gas flow rate was calculated to be about 8 kg/hr (18 lb/hr).

The flow rate of pokehole gases was also measured using a hot wire anemometer. Each pokehole was enclosed by a metal container equipped with a sample port. Velocity measurements were taken both with and without a poking rod inserted. Observations of plant operator practices indicated that the poking rod was left in the pokehole approximately 3 minutes, and that this occurred about once every 4 hours. Using this information, the weighted average flow rate of pokehole gases was calculated as 6 kg/hr (13 lb/hr).

The cyclone dust flow rate was calculated by weighing the amount of dust collected over the 96-hour material balance period. This was accomplished by emptying the cyclone at the beginning of the test period and then again 96 hours later. Tared, large metal containers were used to catch and weigh the cyclone dust. The average cyclone dust flow rate was calculated at 0.7 kg/hr (1.5 lb/hr).

Velocity traverses of the low-Btu product gas line were made several times during the sampling period. Numerous samples for fixed gas analysis were also taken. The results of these measurements indicated an average product gas flow rate of 4680 m^3/hr (165,000 SCFH) at 21°C (70°F) and 1 atmosphere pressure. The average gas molecular weight was 24.3 indicating a product gas flow rate of 4800 kg/hr (10,600 lb/hr).

2.3.2 Mass Balances

Samples of the inlet and outlet streams from the process were collected over the same 96-hour period. These samples were either analyzed individually and the results averaged (the case for gas samples) or composited to form one physically averaged sample prior to analysis. The average compositions are presented in Table 2-2. The 95% confidence intervals presented for the results are based on calculated standard deviations of results over the time period, historical accuracy and precision for the analytical technique, and estimates of sample variability based on experience with similar samples.

From the compositional results and mass flow rate determinations, material balances for total mass, ash, carbon, nitrogen, oxygen, hydrogen and sulfur were calculated according to the general expression:

$$\sum_{i}^{\text{in}} M_i X_i (j) = \sum_{k}^{\text{out}} M_k X_k (j)$$

where,

$\sum_{i}^{\text{in}} M_i X_i(j)$ = the summation of the mass flows of the component j in the incoming streams (kg/hr)

$\sum_{k}^{\text{out}} M_k X_k(j)$ = the summation of the mass flows of the component j in the outgoing streams (kg/hr)

M_i M_k = the mass flow of the ith or kth stream (kg/hr)

X_i (j), X_k(j) = the weight fraction of the component j in the ith or kth stream.

The results of these calculations using the flow rates in Table 2-1 and the compositions in Table 2-2 are presented in Table 2-3. The error limits for the total summations are derived from analytical and flow rate confidence intervals through the material balance calculations according to the following equations:

TABLE 2-2. AVERAGE COMPOSITIONS OF MAJOR PROCESS STREAMS AT THE GLEN-GERY GASIFICATION FACILITY

Component	Coal	Inlet Air*	Gasifier Ash	Cyclone Dust	Coal Hopper Gas*	Product Gas*
Ash-wt%	11.7 (±10%)		65.8 (±10%)	24.7 (±10%)		
Carbon-wt%	81.2 (±10%)		33.0 (±10%)	70.1 (±10%)		
CO_2-vol%		0.02 (±100%)			4.6 (± 6%)	5.5 (± 5%)
CO -vol%					23.6 (±11%)	25.5 (± 7%)
CH_4-vol%					0.22 (±12%)	0.23 (±17%)
Nitrogen-wt%	0.82 (± 8%)		0.18 (± 8%)	0.62 (± 8%)		
N_2 -vol%		79 (± 2%)			54.1 (± 4%)	51.6 (± 1%)
Oxygen-wt%	2.6 (±10%)		0.30 (±10%)	0.95 (±10%)		
O_2 -vol%		21 (± 10%)			3.0 (±70%)	0.90 (±20%)
H_2O-wt%	0.94 (±10%)		0.25 (±10%)	0.71 (±10%)		
H_2O-vol%		23 (± 15%)			5.9 (±100%)	5.9 (±10%)
Hydrogen-wt%	2.14 (±10%)		0.27 (±10%)	1.4 (±10%)		
H_2 -vol%					14.5 (± 15%)	16.3 (± 4%)
Sulfur-wt%	0.62 (±10%)		0.20 (±10%)			
H_2S-vppm					290 (± 22%)	690 (±22%)
COS-vppm					60 (± 19%)	93 (±19%)
SO_2-vppm					5 (±250%)	21 (±250%)
CS_2-vppm					< 0.5	0.8 (± 80%)

*All gas compositions on a dry gas basis except moisture content

NOTE: The numbers in parentheses represent the 95% confidence interval for the data.

TABLE 2-3. MATERIAL BALANCES FOR THE GLEN- GERY GASIFICATION FACILITY

	Total Mass (kg/hr)	Ash (kg/hr)	Carbon (kg/hr)	Nitrogen (kg/hr)	Oxygen (kg/hr)	Hydrogen (kg/hr)	Sulfur (kg/hr)
Coal	790	92	640	6.5	27	18	4.9
Inlet Air	3570	-	-	2740	790	-	-
Water Vapor in Inlet Air	700	-	-	-	620	78	-
Total In	5060 ± 300	92 ± 13	640 ± 90	2750 ± 210	1440 ± 140	96 ± 12	4.9 ± 0.7
Gasifier Ash	74	49	24	0.13	0.4	0.2	0.15
Cyclone Dust	0.7	0.4	0.5	0.004	0.01	0.01	0.10
Coal Hopper Gas	8	-	1.1	5	2.3	0.11	0.004
Pokehole Gas*	6	-	1.0	4	1.7	0.11	0.006
Product Gas	4800	-	700	2690	1330	86	5.1
Total Out	4900 ± 530	50 ± 30	730 ± 80	2700 ± 430	1330 ± 110	86 ± 9	5.4 ± 1.1

*Pokehole gas assumed to be same composition as product gas

-Assumed to have negligible contribution to the mass balance

$$S^2(Q) = \sum_{i}^{n} \left(\frac{\partial Q}{\partial qi}\right)^2 S^2(qi)$$

where,

$S(Q)$ = the variance in Q
Q = the material balance value which is a function of the qi's
qi = the ith independent flow rate or composition used to calculate Q.

The 95% confidence interval is then given by 2 S(Q).

If the confidence limits for total in and total out overlap, the material balance closes within the limits of the known or estimated variances in the data. This is the case for all of the balances calculated except ash. The ash balance is dependent on the coal and gasifier ash flow rates. Since the carbon and sulfur balances, which are primarily dependent on the coal flow rate, close within the expected limits, the most likely data in error is the gasifier ash flow rate. Forced closure of the ash balance estimates that the actual gasifier ash flow rate could be as high as 160 kg/hr (350 lb/hr).

SECTION 3.0

SAMPLING METHODOLOGY

Twelve process and waste streams were sampled during the Wellman-Galusha test program. Presented in this section are a description of each sampling point and the sampling methods employed.

3.1 DESCRIPTION OF SAMPLING POINTS

The sampling points for the Glen-Gery test program are numerically denoted in Figure 3-1. Detailed discussions of the sampling locations are provided in the following text.

3.1.1 Coal Feedstock (1)

At approximately 4-hour intervals, a coal bucket elevator and a coal weigh belt are used to "coal-up", i.e., refill the coal hopper. During Radian's test program, coal feed samples were collected as the coal fell from the weigh belt into the hopper. Samples were taken at 2-3 minute intervals throughout the 10-15 minute period required to "coal-up".

3.1.2 Coal Hopper Gases (2)

Fugitive gases are continually discharged to the atmosphere from the coal hopper. This occurs because: 1) low-Btu product gases which accumulate in the lower portion of the coal feed hopper are displaced during each coal feeding cycle, and 2) low-Btu gas leaks past the coal hopper slide valves. To obtain samples of these gases, and to estimate their flow rate, the hopper was enclosed with a polyethylene sheet. Gas samples were taken through a sample port which was installed in the plastic enclosure.

3.1.3 Gasifier Jacket Makeup Water (3)

Plant service water is added to the gasifier water jacket to replace water lost through evaporation. Samples of gasifier jacket makeup water were collected from a sample port installed in a makeup water line.

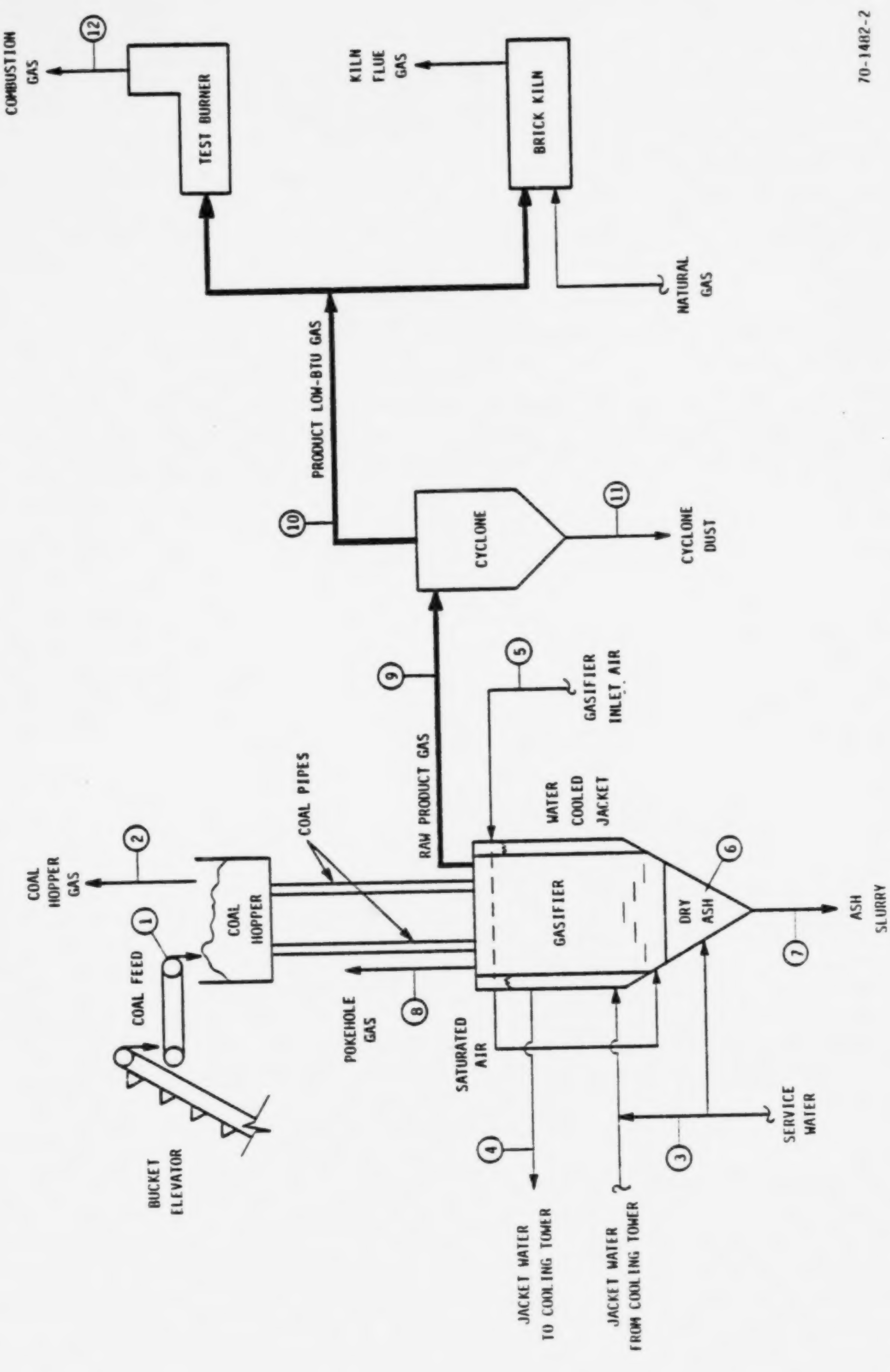

COAL HOPPER GAS
2
COAL PIPES
COAL HOPPER
1
COAL FEED
BUCKET ELEVATOR
POKEHOLE GAS
8
GASIFIER
RAW PRODUCT GAS
WATER COOLED JACKET
DRY ASH
6
ASH SLURRY
7
SATURATED AIR
4
3
SERVICE WATER
JACKET WATER TO COOLING TOWER
JACKET WATER FROM COOLING TOWER
9
5
GASIFIER INLET AIR
CYCLONE
10
11
CYCLONE DUST
PRODUCT LOW-BTU GAS
TEST BURNER
12
COMBUSTION GAS
BRICK KILN
KILN FLUE GAS
NATURAL GAS
70-1482-2

Figure 3-1. Sampling Locations for the Glen-Gery Gasifier

3.1.4 Gasifier Jacket Water (4)

A forced draft cooling tower is used to cool the recirculated gasifier jacket water. Samples of this stream were collected during Radian's tests from a sample port installed in the line leading to the cooling tower.

3.1.5 Gasifier Inlet Air (5)

Reactant air for the gasifier is supplied by a turboblower. The air intake for the blower is located beneath the "catwalk" floor for the coal hopper. Inlet air samples were collected directly above the air intake.

3.1.6 Ash (6)

Gasifier ash accumulates in an ash hopper at the bottom of the gasifier. In order to collect dry ash samples, i.e., before the ash is quenched prior to ash removal, the ash discharge gate was partially opened and a sample corer was inserted into the ash hopper.

3.1.7 Ash Quench Water (7)

Ash is removed from the gasifier ash hopper as an aqueous slurry and trucked to an on-site disposal area. A sample of the ash quench/sluice water was collected as it drained from the ash truck.

3.1.8 Pokehole Gases (8)

The flow rates of emissions from six different pokeholes were measured during the test program. This was accomplished by placing a large metal container, equipped with a sample port, over the pokehole. Flow measurements were made using a hot wire anemometer. The composition of this stream was assumed to be similar to that of the product gas.

3.1.9 Cyclone Inlet (9)

Hot, raw low-Btu gas exits the top of the gasifier through a 1 m (3 ft) horizontal run of refractory brick-lined duct (61 cm or 24 in I.D.) before entering the hot gas cyclone. A 10 cm (4 in) sample port equipped with a gate valve was installed (in the horizontal plane) in the brick-lined duct. The gas stream was accessed with a sample probe through a packing gland attached to the gate valve.

3.1.10 Product Gas (10)

Samples of low-Btu product gas were collected from a vertical run of duct (51 cm or 20 in I.D.) downstream of the hot gas cyclone. A sample port similar to that used for the cyclone inlet was used to gain access to the gas stream. Approximately 10 duct diameters of straight duct were upstream of the sample port location.

3.1.11 Cyclone Dust (11)

Dust collected by the hot gas cyclone is periodically emptied into a front-end-loader for disposal with the gasifier ash. Samples were obtained as the collected particulates fell from the cyclone discharge chute.

3.1.12 Test Burner Combustion Gases (12)

A test burner was used to generate the combustion products of low-Btu gas produced from anthracite coal. The combustion gas samples were collected from the burner flue through an 8 cm (3 in) sample port (SASS train run and impinger samples) and through a 0.64 cm (0.25 in) sample port (gas chromatograph samples). Samples of the low-Btu fuel gas were also collected. The sampling location for these samples was a 0.64 cm (0.25 in) sample port installed in the inlet line to the test burner gas pump.

3.2 SAMPLING METHODOLOGY

Samples from eleven of the twelve streams just discussed were obtained for physical, chemical, and/or biological analyses as part of the Wellman-Galusha test program (flow rate measurements only were made on the pokehole gases). The following sections describe the sampling methods used to obtain these samples. For convenience of presentation, the sampling methods are broken down into the type of sample being collected:

- entrained particulates in gas streams,
- gases,
- liquids, and
- solids.

Table 3-1 presents the sampling schedule for the Glen-Gery test program. The 96-hour material balance period extended from the morning of March 30 through the morning of April 2.

3.2.1 Entrained Particulates

Three gas streams were sampled for entrained particulates:

- gasifier inlet air,
- raw product gas (cyclone inlet), and
- clean product gas (cyclone exit).

For the gasifier inlet air stream, a high volume (hi-vol) sampler was used to obtain particulate loading data. For the cyclone inlet and outlet streams both instack filters (for particulate loadings) and cascade impactors (for particle size distribution) were used. The high volume source assessment sampling system (SASS train) also was used to obtain particulate samples. However, this method will be discussed in the section on gas stream sampling.

High Volume Sampler

A high volume sampler (hi-vol) was used to obtain particulate loading information on the gasifier inlet air stream.

TABLE 3-1. SAMPLING SCHEDULE - WELLMAN-GALUSHA SOURCE TEST EVALUATION PROGRAM

Sample Collected	Sample Collection Date (Number of Samples Collected) 3/27	3/28	3/29	3/30	3/31	4/1	4/2	4/3	4/4	4/5	4/6	4/7	4/8
Solid Samples													
Coal feed			2	2	2	4	6	2					
Dry ash			2	2	2	2	2	2	3				
Cyclone dust					2								
Product Low-Btu gas													
Gases - grab sample													
- Fixed gases[a]	1	4	4	2	3	3	5	3					
- C_1-C_4 hydrocarbons		1	4	3	2	4	3	3					
- Sulfur species[b]		5	4	3	5	5	4	3					
Gases - impinger samples													
- CN^- and SCN^-					2			2				5	
- NH_3					3			3				5	
- Carbonyls[c]					2			2					
- Total sulfur				1	3			3				3	
- Trace elements							1						
SASS train						1							
Particle Sizing						3							
Combustor Flue Gases													
Gases - grab sample													
- Fixed gases[a]												3	2
- C_1-C_4 hydrocarbons												2	1
- Sulfur species[b]												3	3
Gases - impinger samples													
- CN^- and SCN^-												5	
- NH_3												5	
- Carbonyls												1	
- Total sulfur												3	
- NO_x (natural gas)										4			2
- NO_x (Low-Btu gas)												3	
SASS train													1
Coal Hopper Gases													
Gases - grab sample													
- Fixed gases[a]					1	3		7					
- C_1-C_4 hydrocarbons								1					
- Sulfur species[b]								1					
Gases - impinger samples													
- CN^- and SCN^-								1					
- NH_3								1					
- Carbonyls								1					
Particulates								1					
Inlet Air to Gasifier													
Particulates						1		1	1				
Organics						1		1	1				
Service Water					1	1	1	1					
Jacket Water					1	1	1	1					
Ash Sluice Water								1					
Area Hydrocarbons													
Lower Level												1	
Upper Level												1	
Poke Hole Gases (4 holes)													
Without rod-closed							1						
With rod-open							1						
Cyclone Efficiency													
Inlet particulates			3	2									
Outlet particulates			3	2	3		4	3					

[a] Fixed gases: CO, H_2, N_2, O_2, CO_2, CH_4.

[b] Sulfur species: H_2S, COS, CS_2, SO_2

[c] Carbonyls: $Ni(CO)_4$, $Fe(CO)_5$

The hi-vol sampler (see Figure 3-2) consisted of a 20 cm x 25 cm (8 in x 10 in) glass-fiber filter followed by a vacuum cleaner type motor for pulling the gas sample through the filter. The filter was rated at 99.9% efficiency for removing 0.3μm DOP particles. A pitot tube was used to monitor the volume of gas sampled. The hi-vol samples were obtained over nominally an 8-hour period. As described in Section 3.1.5, the hi-vol was stationed on the coal hopper floor "catwalk" directly above the gasifier air intake.

Instack Filter

Instack alundum thimble-type filters were used to obtain particulate loadings for the raw product gas (cyclone inlet) and clean product gas (cyclone exit) streams. Figure 3-3 illustrates the sampling train used for these particulate loading determinations. It consisted of a stainless steel probe fitted with an alundum thimble holder, sample transfer lines, four impingers, and pumping and metering equipment. A preweighed alundum thimble was placed in the thimble holder to collect the particulate matter. The first two impingers contained 250 ml of acidic H_2O_2 while the third impinger was dry. The fourth impinger contained a preweighed amount of silica gel.

Prior to sampling, the following stream properties were determined:

- velocity profile (EPA Method 1 and 2, Ref. 2, 3),
- average gas molecular weight (gas chromatography),
- gas moisture content (EPA Method 4, Ref. 4),
- gas temperature (thermocouple), and
- absolute pressure.

Sampling nozzle size and isokinetic sampling rates were calculated from these data. The sampling probe was first inserted into the gas stream and the alundum thimble was allowed to warm up to the gas stream temperature to prevent water vapor from condensing in the thimble. Particulate samples were then collected isokinetically at six traverse points over a total sampling period ranging from 30 to 60 minutes. After sampling, the thimble holder was removed from the gas stream and a piece of aluminum foil was

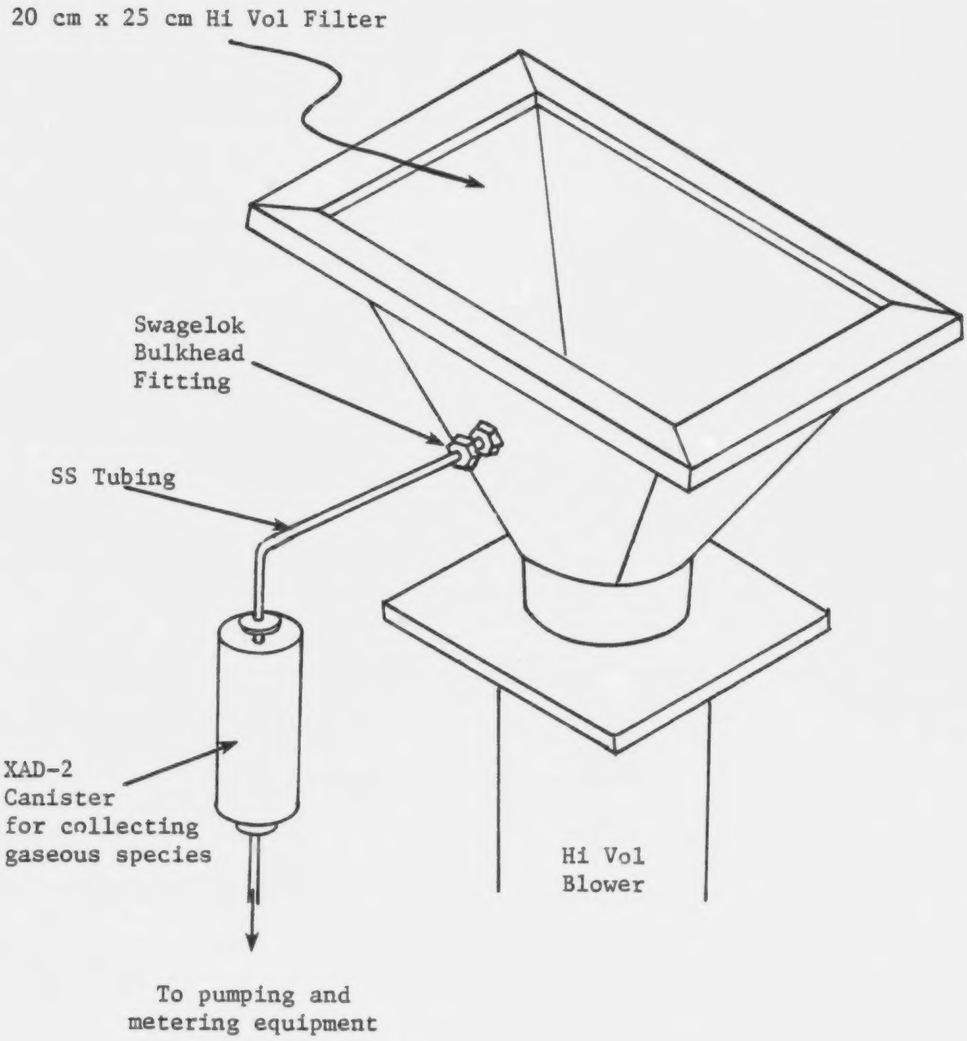

20 cm x 25 cm Hi Vol Filter
Swagelok Bulkhead Fitting
SS Tubing
XAD-2 Canister for collecting gaseous species
Hi Vol Blower
To pumping and metering equipment

Figure 3-2. High Volume Sampler

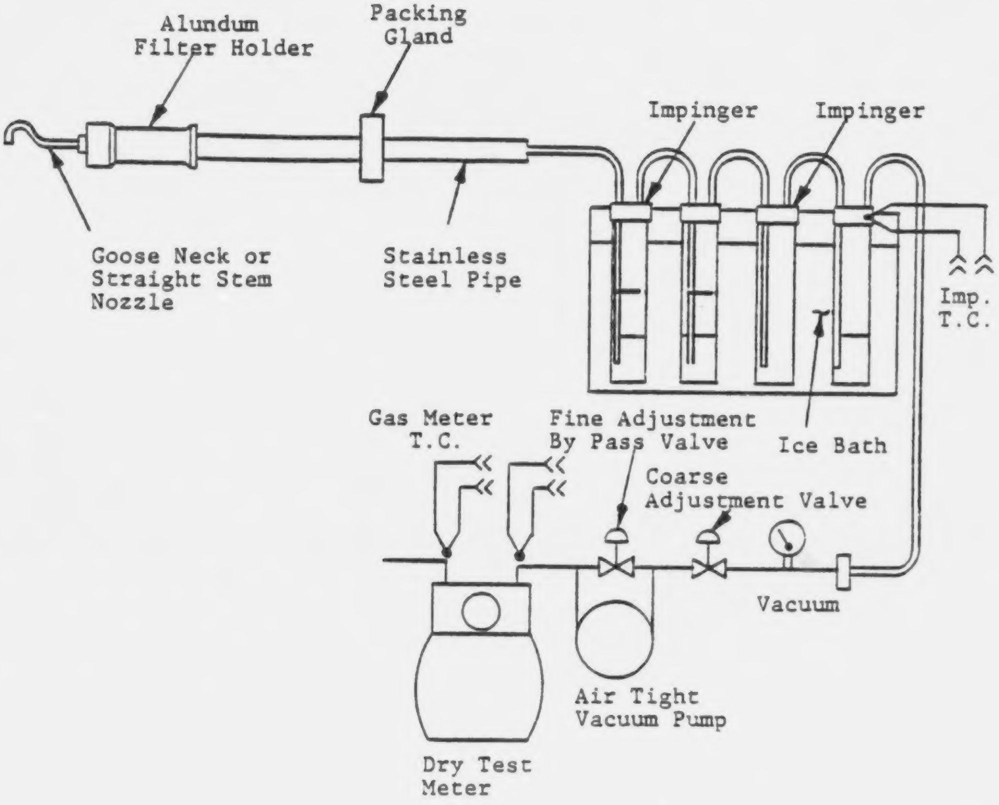

Alundum Filter Holder
Packing Gland
Impinger
Impinger
Goose Neck or Straight Stem Nozzle
Stainless Steel Pipe
Imp. T.C.
Gas Meter T.C.
Fine Adjustment By Pass Valve
Ice Bath
Coarse Adjustment Valve
Vacuum
Air Tight Vacuum Pump
Dry Test Meter

Figure 3-3. Schematic Diagram of Particulate Sampling Train

placed over the nozzle to eliminate the possibility of combustion taking place in the thimble.

Cascade Impactor

A Brink model B cascade impactor was used for the particle size distribution determinations for both the raw and clean product gas streams. The Brink impactor used by Radian consisted of five collecting stages preceded by a cyclone for coarse particulate removal and followed by a final filter. The impactor was fitted on a stainless steel probe connected to four impingers and pumping and metering equipment. The first two impingers contained 250 ml of acidic H_2O_2, the third was dry, and the fourth contained silica gel.

The sampling probe was inserted into the gas stream and allowed to warm up to the gas temperature to prevent condensation of water vapor in the impactor. Sampling nozzle size and sampling rate were determined in a manner identical to that used for the particulate loading determinations. However, because the collection mechanism of the Brink impactor is based on a constant gas flow rate into the impactor, samples were taken only at the three traverse points which had gas velocities with $\pm10\%$ of the average gas velocity. Sampling times ranged from 15 to 90 minutes. A piece of aluminum foil was placed over the probe nozzle after its removal from the gas stream to eliminate the possibility of combustion taking place in the impactor.

3.2.2 Gases

Five gas streams were sampled as part of the Glen-Gery test program:

- gasifier inlet air,
- coal hopper gases,
- clean product gas (cyclone exit),
- clean product gas (test burner inlet), and
- test burner flue gas.

As shown in Table 3-2, four sampling methods were used:

- XAD-2 Cartridge (Hi-vol),
- Grab,
- Impinger, and
- SASS Train.

These sampling methods are described in the following sections.

XAD-2 Cartridge (Hi-vol)

The gasifier inlet air was sampled for organics by pulling a slipstream from the hi-vol sampler through XAD-2 resin. The resin was contained in a stainless steel cartridge connected to a sample tap installed downstream of the hi-vol filter (see Figure 3-2). Samples were taken over approximately an eight-hour period.

Grab Sampling

Grab samples for fixed gases, sulfur species, and light hydrocarbons analyses were obtained by the sampling system shown in Figure 3-4. This system consisted of a heated teflon sampling tube and a teflon membrane filter followed by an osmotic gas dryer, a teflon lined pump, a rotometer, and a sample container. Access to the clean product gas stream was through a 10 cm (4 in.) sample port installed in the gas line. Access to the coal hopper gases was through a 3.8 cm (1.5 in.) sample port installed in the polyethylene sheet covering the hopper (see Section 3.1.2). The test burner flue gas was sampled through a 0.64 cm (0.25 in.) sample port in the burner flue.

The temperature of the gas sample was kept above the water dew point until the gas had been dried in order to avoid losses due to condensation. The teflon membrane filter provided an inert method to protect the osmotic dryer from particulates in the gas stream. All portions of the sampling system which came in contact with the gas stream were constructed of stainless steel, glass or teflon. An exception to this was the proprietary inert membrane in the dryer.

TABLE 3-2. GAS SAMPLING METHODS USED IN GLEN-GERY TEST PROGRAM

Stream	Sampling Method	Analytical Parameters
Gasifier Inlet Air	XAD-2 cartridge (Hi-vol)	Organics
Coal Hopper Gases	Grab	Fixed gases, sulfur species, and light hydrocarbons
	Impingers	NH_3, CN^-, SCN^-, and $Me(CO)_x$
Clean Product Gas (Cyclone Exit)	Grab	Fixed gases, sulfur species, and light hydrocarbons
	Impingers	NH_3, CN^-, SCN^-, $Me(CO)_x$, total sulfur, and trace elements
	SASS train	Particulates, organics, and trace elements
Clean Product Gas (Test Combustor Inlet)	Impingers	NH_3, CN^-, SCN^-, and total sulfur
Test Combustor Flue Gas	Impingers	NH_3, CN^-, SCN^-, $Me(CO)_x$, and total sulfur
	Grab	Fixed gases, sulfur species, and light hydrocarbons
	SASS train	Particulates, organics, and trace elements

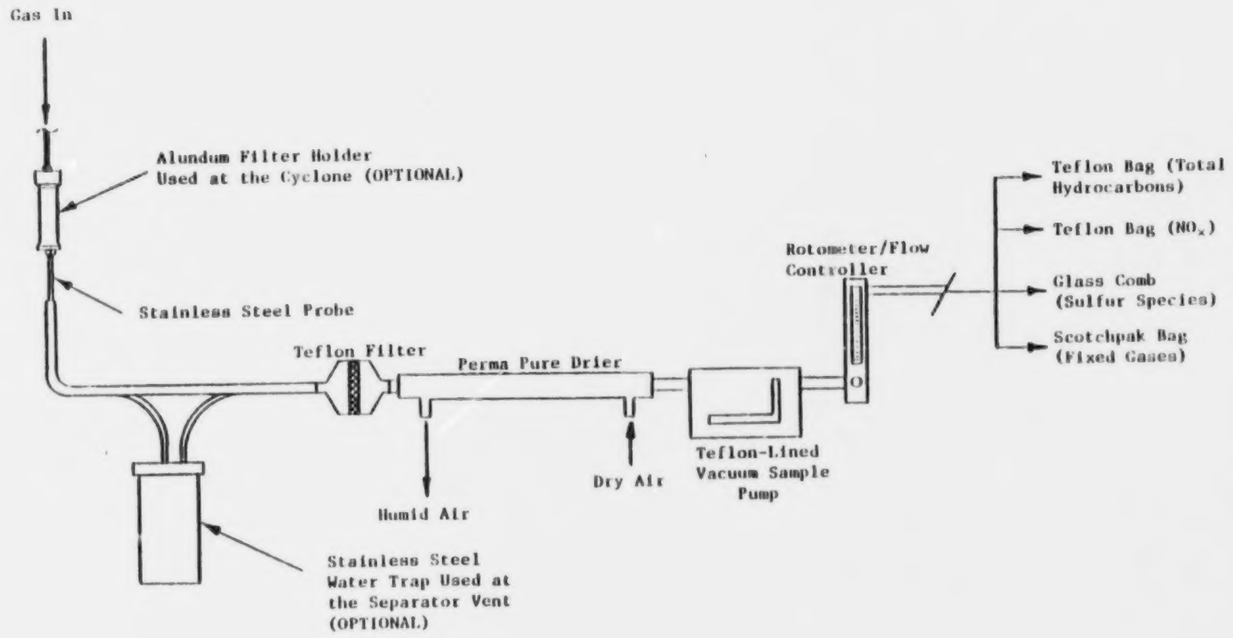

Gas In
Alundum Filter Holder Used at the Cyclone (OPTIONAL)
Stainless Steel Probe
Teflon Filter
Perma Pure Drier
Humid Air
Dry Air
Teflon-Lined Vacuum Sample Pump
Rotometer/Flow Controller
Teflon Bag (Total Hydrocarbons)
Teflon Bag (NO$_x$)
Glass Comb (Sulfur Species)
Scotchpak Bag (Fixed Gases)
Stainless Steel Water Trap Used at the Separator Vent (OPTIONAL)

Figure 3-4. Grab Sample Collection and Preparation System

The sampling train was well purged prior to filling the sample container. All containers were purged a minimum of five sample volumes prior to sample collection. Teflon bags with stainless steel valves were used for hydrocarbon samples, polyethylene bags with stainless steel valves for fixed gases, and glass bombs for sulfur species.

Impinger Train Sampling

Impinger sampling trains were used to collect vapor-phase components from the coal hopper gases, clean product gas, and test burner flue gas. The collection principle of the impinger train is the dissolution and/or reaction of vapor-phase components with an impinger solution. The solutions used by Radian for the Glen-Gery test program were:

Component Being Collected	Impinger Solution	# of Impingers
NH_3	5% H_2SO_4	2
CN^-, SCN^-	10% NaOH	2
$Me(CO)_x$	KI/I_2 in 3% HCl	2
Total Sulfur	6% H_2O	2
	2% $Zn\ (C_2H_3O_2)_2$	2
	KOH/C_2H_5OH	1
Trace Elements	20% HNO_3	2
	dry	1
	20% KOH	2

Standard 500 ml Greenberg-Smith impingers were used for sampling the clean product gas and test burner flue gas, while miniature impingers were used for the coal hopper gases. These two systems are discussed in the following sections.

Impingers (Greenberg-Smith) - With the exception of the impinger solutions, the impinger sampling train used for the clean product gas (both at the cyclone exit and the test burner inlet) and test burner flue gas was identical to that used for the particulate loading determinations (see Figure 3-3). Access to the clean product gas at the cyclone exit was through a 10 cm (4 in.) sample port, while at the test burner inlet a 0.64 cm

(0.25 in.) sample port was used. The burner flue gas was sampled through an 8 cm (3 in.) sample port in the burner flue.

Most samples were taken isokinetically at standard traverse points over a 30-minute period. However, some of the metal carbonyl sampling periods were extended to 2½ hours and the sample for trace elements was taken over approximately a 9-hour period.

Impingers (Miniature) - Miniature impingers were used to sample the coal hopper gases. The sampling train consisted of a small cyclone and glass fiber filter (for removal of particulates) suspended inside the covered coal hopper. The particulate collection unit was connected by plastic tubing to three 100 ml impingers arranged in series. The first two were filled with approximately 25 ml of impinger solution, but the third was dry. A small vacuum pump and rotometer followed the third impinger. Samples for NH_3, CN^-, and SCN were collected over about a 100 minute time period, while sampling for metal carbonyls continued for over 2½ hours.

SASS Train

The high volume source assessment sampling system (SASS train) was used to obtain samples of the clean low-Btu product gas at the cyclone exit and of the test burner flue gas. The SASS train collects particulates, organics and trace elements. A detailed description of the SASS train and its operating parameters is given in the EPA Level 1 procedures manual (Ref. 5). Figure 3-5 is a schematic of the SASS train. The sampling period for the clean product gas (accessed through a 10 cm or 4 in. sample port) was about 2½ hours, while sampling of the test burner flue gas (accessed through an 8 cm or 3 in. sample port) continued for 5 hours and 45 minutes.

3.2.3 Liquids

Grab samples of three liquid streams were taken as part of the Glen-Gery test program. These were:

- gasifier cooling jacket makeup water (service water),

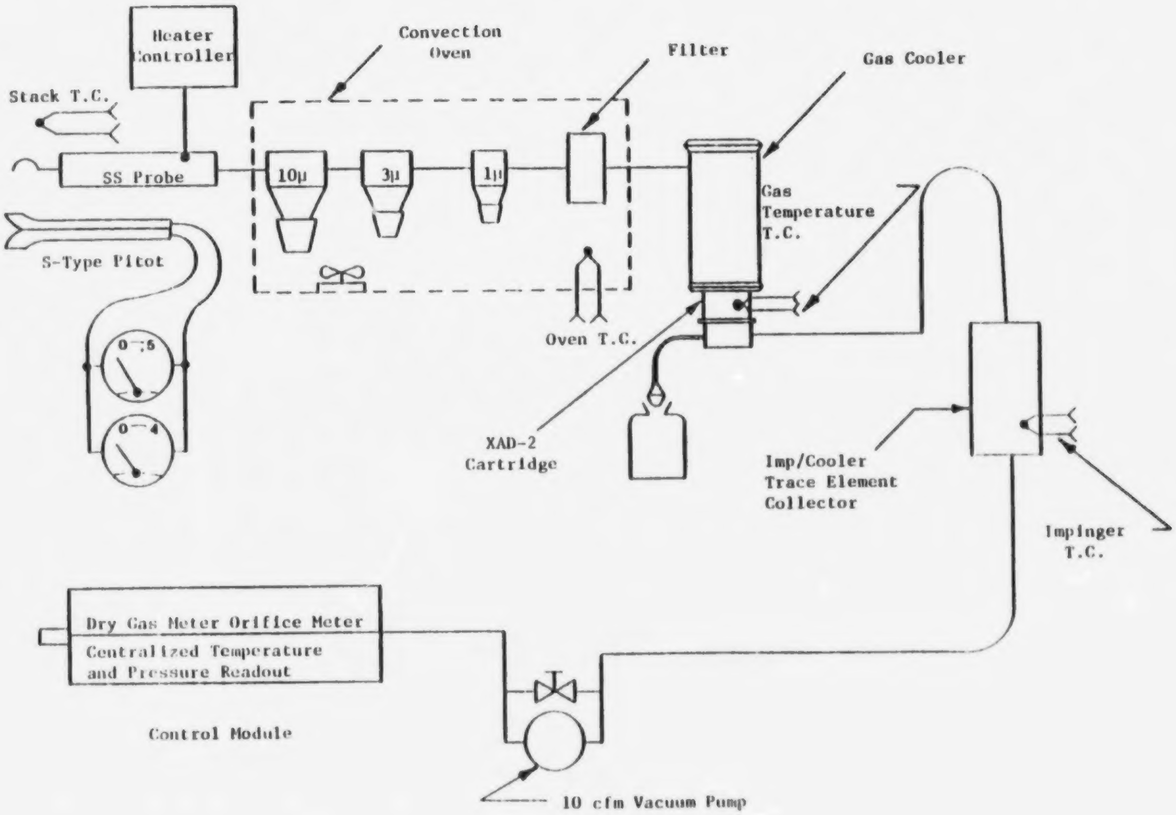

Heater Controller
Stack T.C.
SS Probe
S-Type Pitot
0—.5
0—4
Convection Oven
10μ
3μ
1μ
Filter
Oven T.C.
Gas Cooler
Gas Temperature T.C.
XAD-2 Cartridge
Imp/Cooler Trace Element Collector
Impinger T.C.
Dry Gas Meter Orifice Meter
Centralized Temperature and Pressure Readout
Control Module
10 cfm Vacuum Pump

Figure 3-5. SOURCE ASSESSMENT SAMPLING SCHEMATIC

- recirculating gasifier cooling jacket water, and
- ash sluice water.

Tap sampling techniques were used for obtaining the two gasifier cooling jacket samples. The sample taps were well flushed prior to sample acquisition. The samples were collected in 1 liter polyethylene containers which were first flushed several times with the sample material.

The ash sluice water was sampled as it drained from the ash transport truck. Samples for analysis of inorganics were caught in 1 liter polyethylene containers while samples for analysis of organics were collected in ½ liter glass bottles fitted with teflon caps. These sample containers were also well flushed with sample prior to sample acquisition.

3.2.4 Solids

Grab samples of three solid streams were taken during the Glen-Gery test program. These were:

- coal feedstock,
- gasifier ash (dry), and
- cyclone dust.

The sampling methods used for each of these streams are described in the following sections.

Coal Feedstock

Grab samples of the coal feedstock were taken as the coal fell from the coal weigh belt into the coal hopper. The sampling equipment consisted of an 8 cm x 18 cm x 25 cm (3 in. x 7 in. x 10 in.) polyethylene cup attached to a 1.2 m (4 ft) metal pole. Samples were taken by passing the cup through the falling coal approximately every 2-3 minutes during the 10-15 minutes required to coal-up. This procedure provided a composite sample representative of the coal added to the hopper.

"Coal-up's" normally occurred six times per day. However, due to time considerations, coal samples were taken only during the 8:00 a.m. and 4:00 p.m. "coal-up's". Approximately 20 liters of sample were obtained from each "coal-up". A small portion of this (½ liter) was removed and stored for organic analysis in a glass bottle fitted with a teflon cap. The remaining sample was first reduced to about 2 liters by coning and quartering, and then stored in airtight polyethylene containers.

Gasifier Ash

Before ash is removed from the gasifier, water is added to the ash hopper to aid in ash removal and to help maintain a seal between the gasifier and the atmosphere.

In order to obtain a dry ash sample, sampling took place prior to the introduction of the ash sluice water. A 7.6 cm (3 in.) corer was driven into the ash hopper through the partially opened ash removal gate. This procedure resulted in obtaining approximately 5 kg (11 lb) of dry ash. A small portion of this sample was stored in a glass bottle fitted with a teflon cap for organic analysis. The remaining sample was reduced by coning and quartering and stored in airtight polyethylene containers for inorganic analysis. After the dry ash samples were obtained, the ash removal procedure proceeded normally with the ash slurry being trucked to an on-site disposal area.

Cyclone Dust

Cyclone dust is normally removed from the cyclone weekly and trucked to an on-site disposal area. However, to facilitate the material balance portion of Radian's test program, the cyclone dust was removed at the beginning and end of the 96-hour material balance period. To obtain cyclone dust samples, the dust was collected in large metal containers. From the containers, grab samples were taken and stored in airtight 1 liter polyethylene containers for inorganic analysis and in ½ liter glass bottles fitted with teflon caps for organic analysis.

SECTION 4.0

ANALYTICAL PROCEDURES

Both chemical (inorganic and organic) and biological analyses were performed on the samples obtained at the Glen-Gery test site. In addition, process gas chromatographs were used to continuously monitor the product low-Btu gas for selected inorganic and organic species. Table 4-1 summarizes the analyses performed on each stream sampled, while Figures 4-1 through 4-7 show the analytical scheme used for each sample.

The following sections contain detailed descriptions of the analytical procedures used. The inorganic and organic analyses are described in Section 4.1 and 4.2, respectively, while the bioassay tests are described in Section 4.3. The continuous monitoring of the product gas is discussed in Section 4.4.

4.1 INORGANIC SPECIES ANALYSIS

The inorganic analyses for the Glen-Gery test program included analyzing:

- gas phase species,
- liquids,
- solids, and
- trace elements (solid, liquid, and gaseous samples).

Table 4-1 shows the specific analyses performed for each stream sampled. The inorganic analyses were performed both on-site in Radian's mobile laboratory and off-site at Radian's laboratories in Austin, Texas.

4.1.1 Gas Phase Analytical Procedures

Gas streams sampled at the Glen-Gery facility included product low-Btu gas, coal hopper vent gas and the test burner

TABLE 4-1. SUMMARY OF ANALYSES PERFORMED FOR THE GLEN-GERY TEST PROGRAM

Analysis	Coal	Ash Sluice Water	Dry Ash	Cyclone Dust	Inlet Air to Gasifier (Particulates)	Jacket Water	Service Water	Product Low-Btu Gas	Coal Hopper Gas	Combustion Gases
Trace Elements										
SSMS	x	x	x/✓	x/✓	x	x	x	x		x
Gas Analysis										
Fixed Gases[b]								x	x	x
Sulfur Species[c]								☒	x	x
HCN								x	x	x
HSCN								x	x	x
NH_3								☒	x	x
NO_x								x		x
$Ni(CO)_4$								x	x	x
$Fe(CO)_5$								x	x	x
Total Sulfur								x		
$C_1 - C_6$								☒	x	x
Liquid Analysis										
pH				✓						
TDS		x		✓						
TSS		x		✓						
Anions[d]		x	✓	✓						
NH_4^+		x								
COD		x		✓						
BOD		x								
TOC		x								
Solid Analysis										
Proximate/Ultimate	x		x	x						
HHV	x		x	x						
Size Distribution				x				x		
Specific Gravity	x		x	x						
Particle Morphology	x		x	x				x		
Gross α and β	x		x	x				x		
Gravemetric					x			x		x
Organics										
Level 1		x	x/✓	x	+			+		+
Bioassay	x	x	x/✓	x				x/+		x/+

[a] Proximate analysis: moisture, ash, volatiles, and fixed carbon
Ultimate analysis: C, H_2, N_2, S, O_2

[b] Fixed gases: H_2, CO, CO_2, CH_4, N_2

[c] Sulfur species: H_2S, COS, CS_2, SO_2

[d] Anions: PO_4^{-3}, Cl^-, F^-, $S^=$, $SO_4^=$, CN^-, $SCN^=$, $SF_6^=$

x Analysis performed

+ Analysis performed on organic extract

✓ Analysis performed on leachate

☒ Monitored continuously by on-line process gas chromatographs

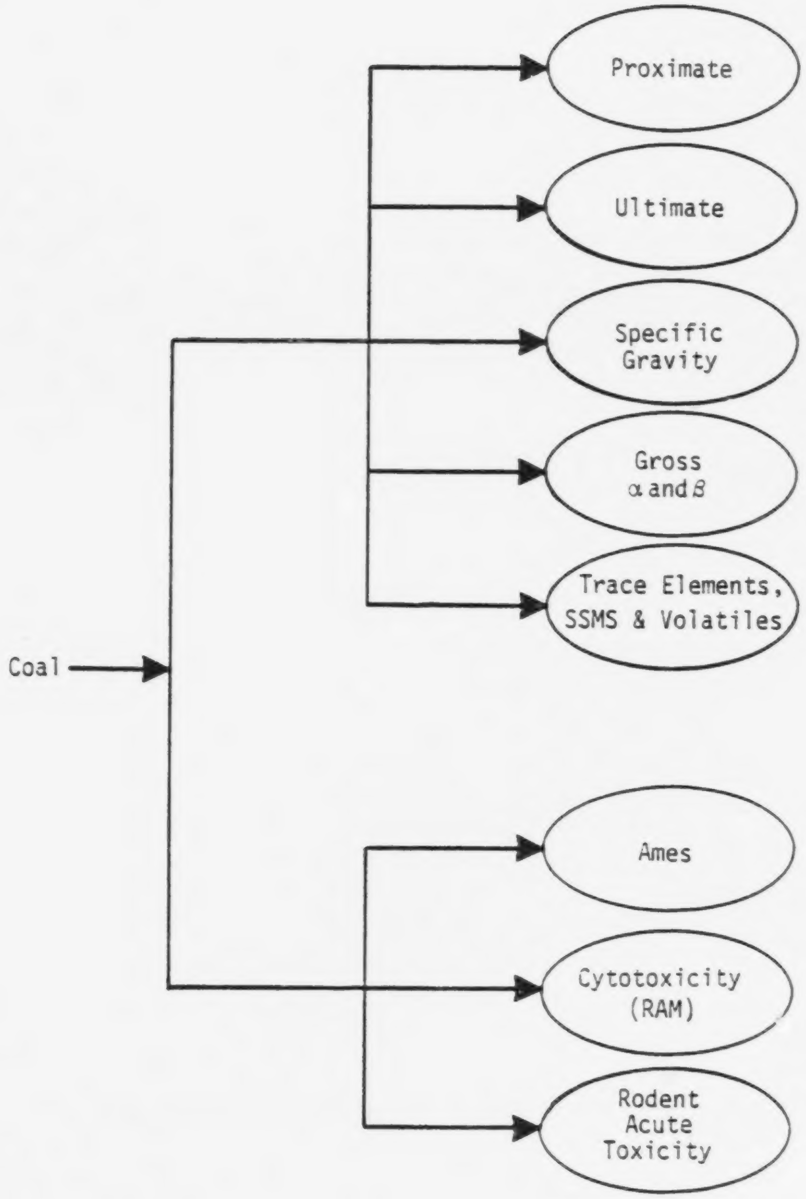

Coal
Proximate
Ultimate
Specific Gravity
Gross α and β
Trace Elements, SSMS & Volatiles
Ames
Cytotoxicity (RAM)
Rodent Acute Toxicity

Figure 4-1. Analytical Flow Scheme for Coal

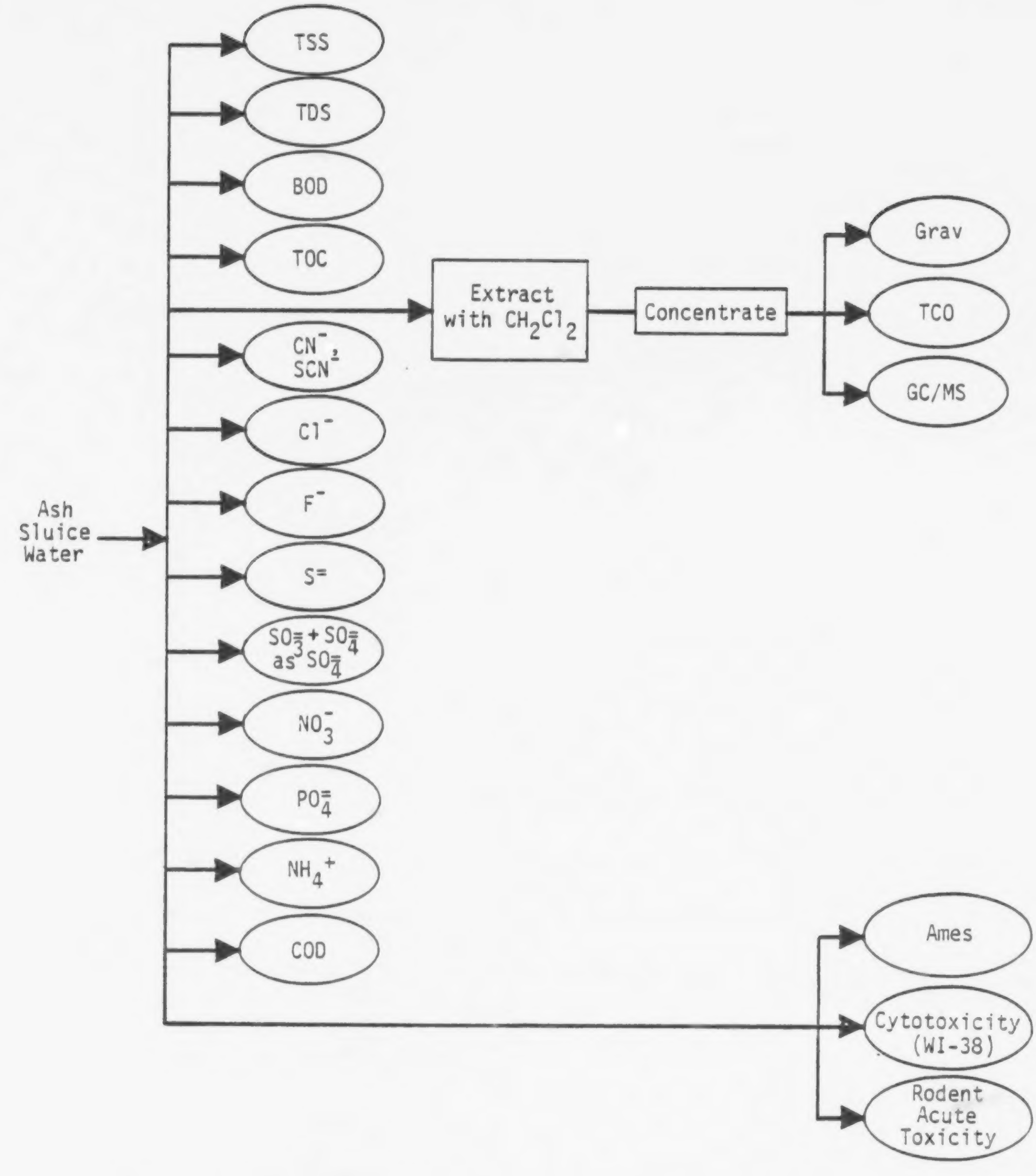

TSS
TDS
BOD
TOC
Extract with CH_2Cl_2
Concentrate
Grav
TCO
GC/MS
CN^-, SCN^-
Cl^-
F^-
Ash Sluice Water
$S^=$
$SO_3^= + SO_4^=$ as $SO_4^=$
NO_3^-
$PO_4^≡$
NH_4^+
COD
Ames
Cytotoxicity (WI-38)
Rodent Acute Toxicity

Figure 4-2. Analytical Flow Scheme for Ash Sluice Water

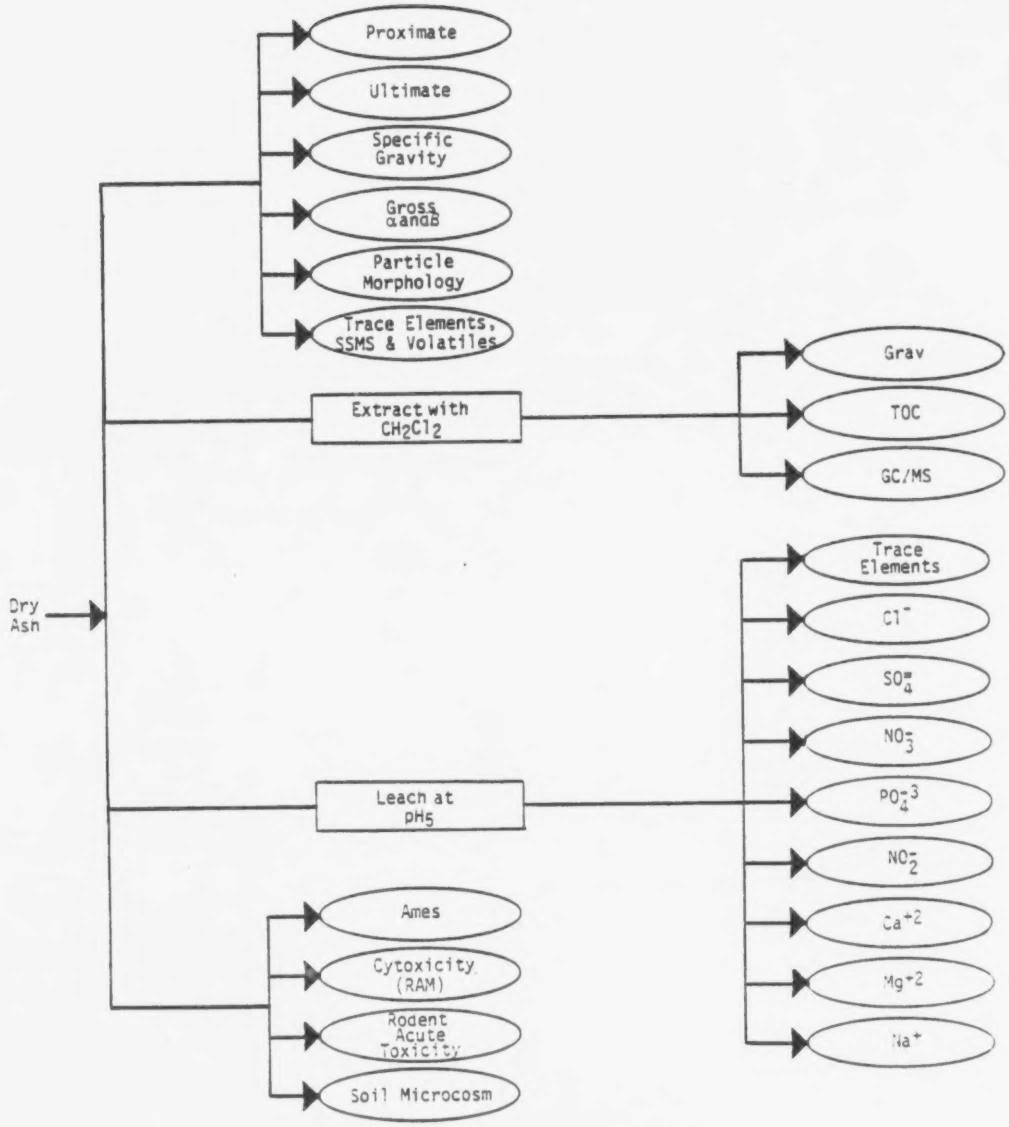

Dry Ash
Proximate
Ultimate
Specific Gravity
Gross α and β
Particle Morphology
Trace Elements, SSMS & Volatiles
Extract with CH_2Cl_2
Grav
TOC
GC/MS
Trace Elements
Cl^-
$SO_4^=$
NO_3^-
PO_4^{-3}
NO_2^-
Ca^{+2}
Mg^{+2}
Na^+
Leach at pH5
Ames
Cytoxicity (RAM)
Rodent Acute Toxicity
Soil Microcosm

Figure 4-3. Analytical Flow Scheme for Dry Ash

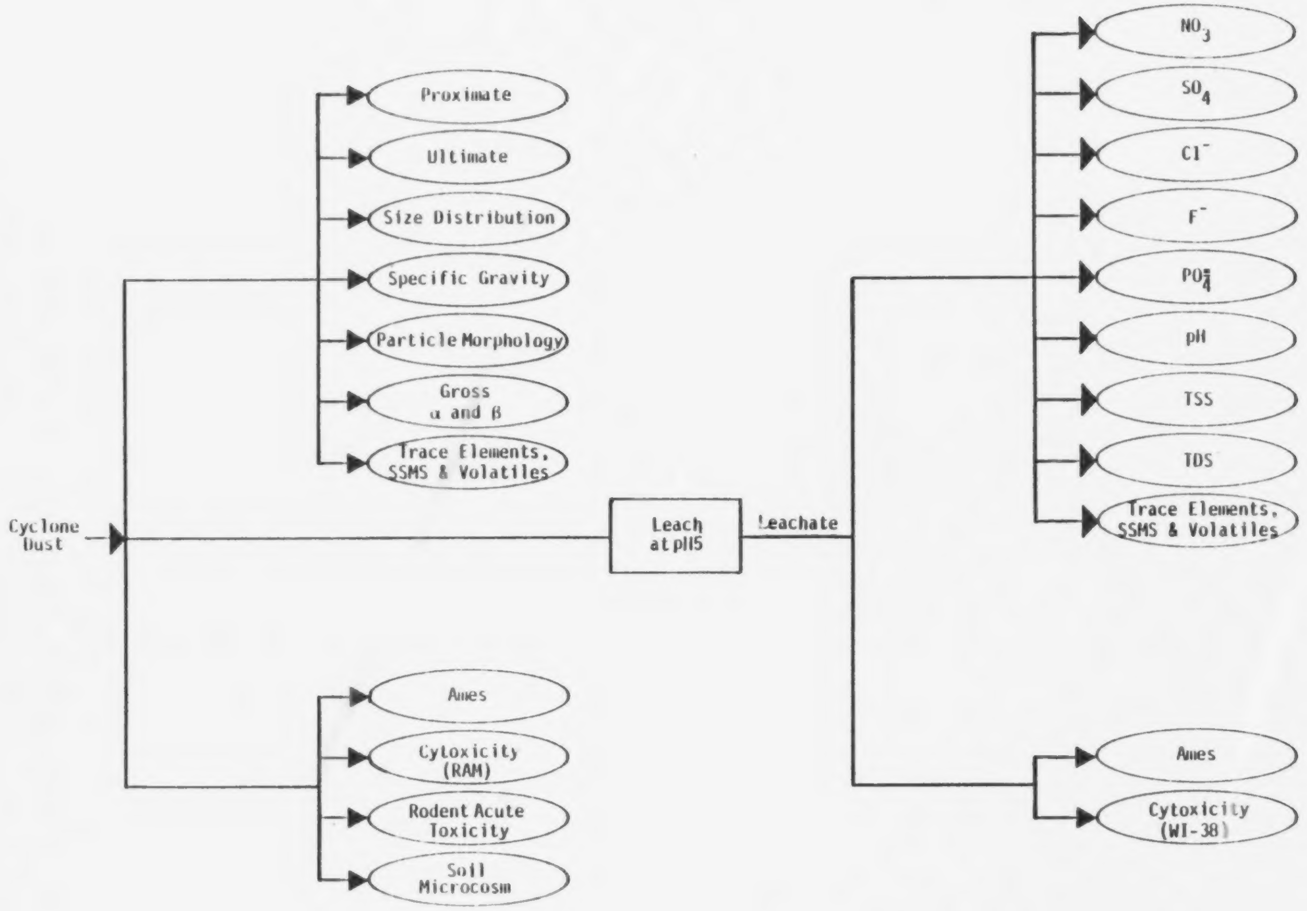

Cyclone Dust
Proximate
Ultimate
Size Distribution
Specific Gravity
Particle Morphology
Gross α and β
Trace Elements, SSMS & Volatiles
Ames
Cytoxicity (RAM)
Rodent Acute Toxicity
Soil Microcosm
Leach at pH5
Leachate
NO_3
SO_4
Cl^-
F^-
$PO_4^{=}$
pH
TSS
TDS
Trace Elements, SSMS & Volatiles
Ames
Cytoxicity (WI-38)

Figure 4-4. Analytical Flow Scheme for Cyclone Dust

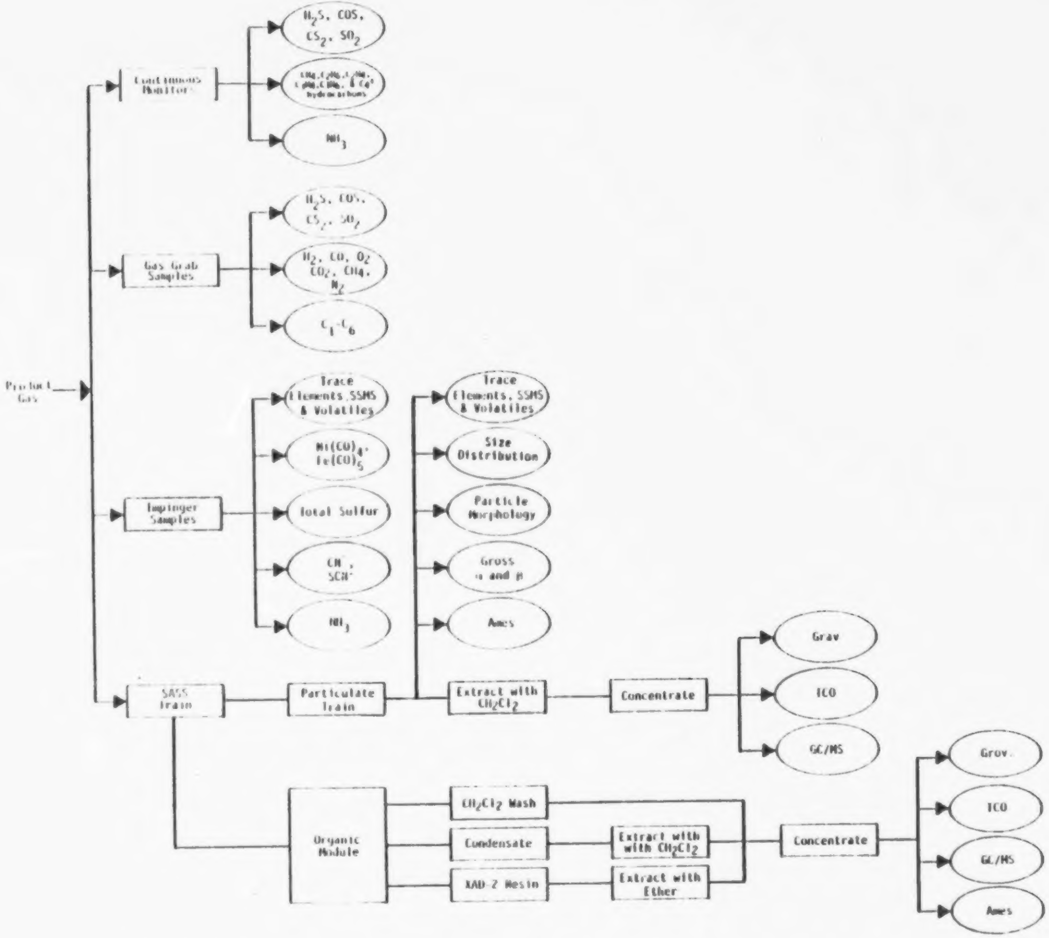
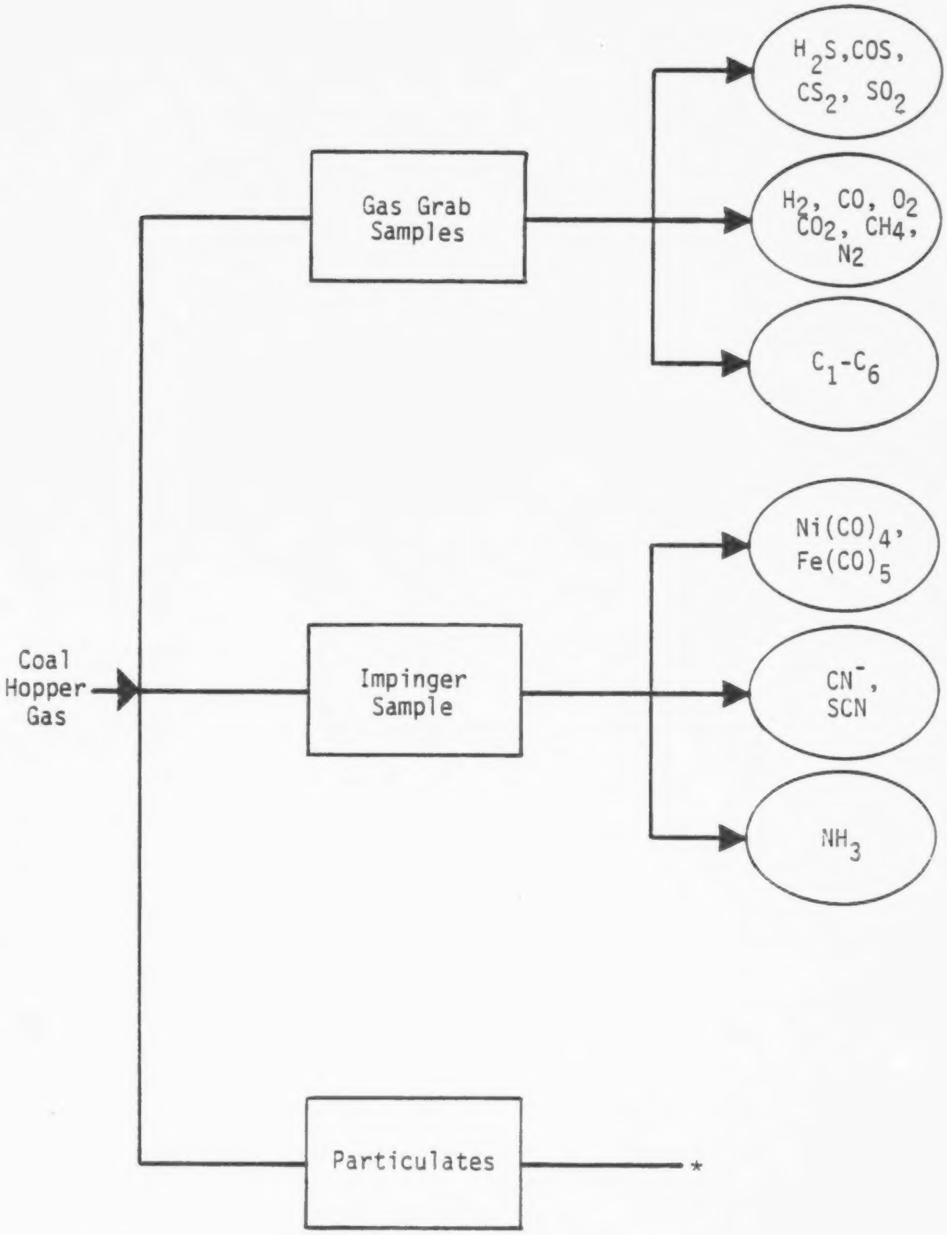
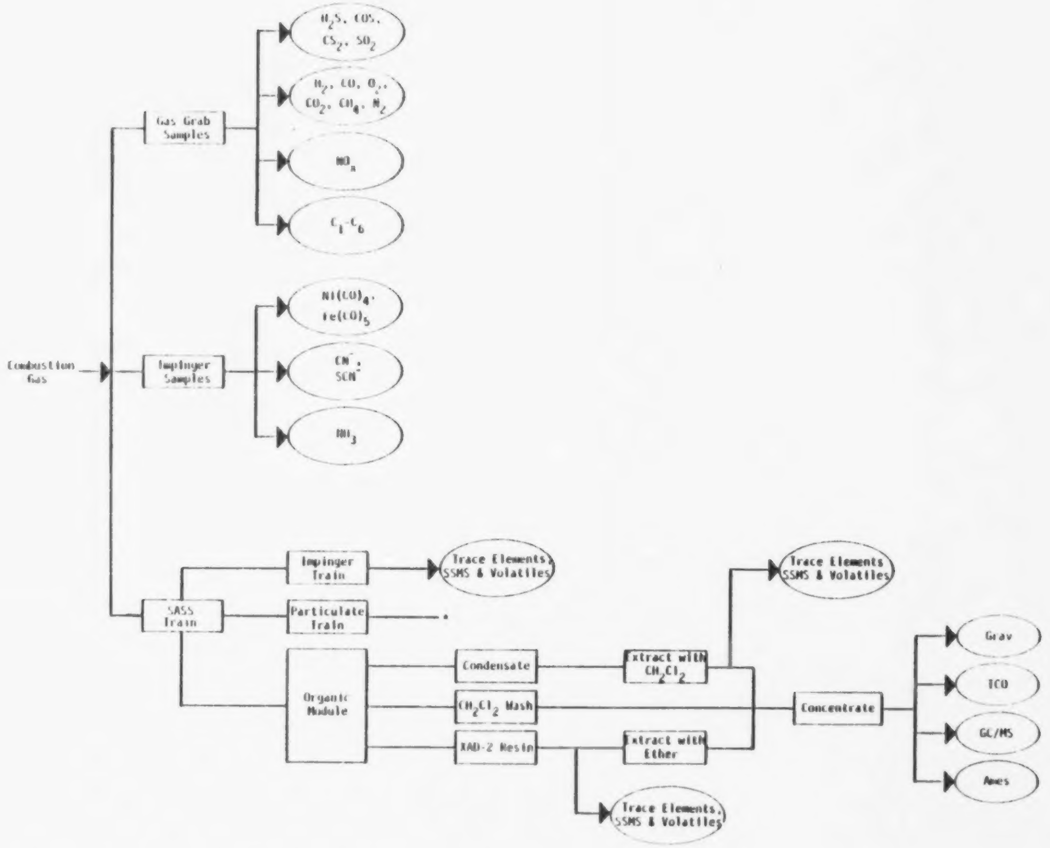

Product Gas
Continuous Monitor
H_2S, COS, CS_2, SO_2
hydrocarbons
NH_3
Gas Grab Samples
H_2S, COS, CS_2, SO_2
H_2, CO, O_2 CO_2, CH_4, N_2
C_1-C_6
Impinger Samples
Trace Elements, SSMS & Volatiles
$Ni(CO)_4$, $Fe(CO)_5$
Total Sulfur
CN^-, SCN^-
NH_3
SASS Train
Particulate Train
Trace Elements, SSMS & Volatiles
Size Distribution
Particle Morphology
Gross α and β
Ames
Extract with CH_2Cl_2
Concentrate
Grav
TCO
GC/MS
Organic Module
CH_2Cl_2 Wash
Condensate
XAD-2 Resin
Extract with with CH_2Cl_2
Extract with Ether
Concentrate
Grav.
TCO
GC/MS
Ames

Figure 4-5. Analytical Flow Scheme for Product Gas


Coal
Hopper
Gas
Gas Grab
Samples
Impinger
Sample
Particulates
*
H_2S, COS, CS_2, SO_2
H_2, CO, O_2 CO_2, CH_4, N_2
C_1-C_6
$Ni(CO)_4$, $Fe(CO)_5$
CN^-, SCN
NH_3

*An inadequate quantity of sample was obtained for analysis

Figure 4-6. Analytical Flow Scheme for Coal Hopper Gas


Combustion Gas
Gas Grab Samples
H_2S, COS, CS_2, SO_2
H_2, CO, O_2, CO_2, CH_4, N_2
NO_x
C_1-C_6
Impinger Samples
$Ni(CO)_4$, $Fe(CO)_5$
CN^-, SCN^-
NH_3
SASS Train
Impinger Train
Trace Elements, SSMS & Volatiles
Particulate Train
*
Organic Module
Condensate
CH_2Cl_2 Wash
XAD-2 Resin
Extract with CH_2Cl_2
Extract with Ether
Trace Elements, SSMS & Volatiles
Trace Elements, SSMS & Volatiles
Concentrate
Grav
TCO
GC/MS
Ames

*An inadequate quantity of sample was obtained for analysis

Figure 4-7. Analytical Flow Scheme for Combustion Gas

flue gas. Gas grab samples were collected from the streams using flexible, aluminized gas sampling bags. The gas grab samples from all three streams were analyzed for:

- fixed gases (CO_2, H_2, O_2, N_2, CH_4, CO), and
- sulfur species (H_2S, COS, SO_2, CS_2, CH_3SH).

Impinger samples were also collected from all three streams and analyzed for:

- HCN,
- HSCN,
- NH_3,
- $Ni(CO)_4$, and
- $Fe(CO)_5$.

In addition, impinger samples for total sulfur analyses were collected from the product low-Btu gas and bomb samples were collected from the test burner flue gas for NO_x analyses.

Fixed Gases

The fixed gas analyses were conducted using a Fisher Model 1200 Gas Partitioner equipped with dual columns and dual thermal conductivity detectors connected in series. A sample from each stream was introduced through a 1 ml sample loop. The loop and sample transport tubing were always flushed with >5 residence volumes of gas before injection. The analyses were carried out under the following instrument operating contions:

Column 1: 6.5' x 1/8" aluminum Columpak PQ

Column 2: 11' x 3/16" aluminum 13x molecular sieve,
60-80 mesh

Carrier Gas: 8.5% H_2 in He

Carrier Flow: 33 cm^3/min

Oven Temp: 50°C

Injector Temp: Ambient

Bridge Current: 275 mA

Elution Order: CO_2, H_2, O_2, N_2, CH_4, CO

Each component was quantified by measuring the peak height and comparing it to a calibration curve. Calibration curves were prepared on-site before testing began. A certified standard mixture containing the six species of interest was analyzed three times on the partitioner and the average peak heights were plotted against the known concentrations. Additional points were generated by analyzing known dilutions of the standard. Nitrogen was used to dilute the standard mixture. The performance of the instrument was checked periodically by analyzing the calibration standard and comparing the result to the standard curves. The partitioner was extremely stable throughout the test period.

Sulfur Species

Grab samples from each of the gas streams were dried and filtered and the sulfur species (H_2S, COS, SO_2, CS_2, CH_3SH) were analyzed on a Tracor Model 560 Gas Chromatograph equipped with a flame photometric detector (FPD). Aliquots were transferred from a gas sampling bomb into a 0.25 milliliter teflon sample loop and injected directly onto the column. Instrument conditions used for these analyses are listed as follows:

Column: 10' x 1/8" teflon, 1% TCEP (1, 2, 3-Tris (2-cyanoethoxy propane)) and 0.5% H_3PO_4 on Carbopak B, 60/80 mesh

Carrier Gas: N_2

Carrier Flow: 20 cm^3/min.

Injector Temp: 150°C

Detector Temp: 190°C

Oven Program: 40°C for 5 min.
20°C/min. to 90°C
90°C for 10 min.

The detector output was recorded and integrated on a Hewlett-Packard Model 3380A Integrator/Plotter.

Calibration was accomplished using a nitrogen stream containing known amounts of the species of interest. The calibration standard was generated in a permeation oven. The same injection technique was used for calibration as for sample analysis. Standards were run each day prior to any sample analysis and multiple standard injections were made until stable, reproducible analyses were obtained. The teflon sample loop was flushed with N_2 prior to any sample injection.

The glass gas sampling bomb was silanized prior to use in order to minimize the sorption of sulfur species onto the walls of the bomb. In addition, >15 residence volumes were flushed through the sampling bomb before collection of any sample.

Cyanide

A two-impinger train containing 10 percent sodium hydroxide was used to collect hydrogen cyanide. Preservation required the immediate on-site removal of sulfide by its precipitation as lead sulfide and subsequent filtration. Solutions were then cooled to 4°C for storage prior to off-site analysis. The samples were analyzed for cyanide by Standard Methods 413B and 413D (Ref. 6). These methods involved acidifying and refluxing the preserved sample in order to liberate hydrogen cyanide. The cyanide gas was collected in an NaOH solution and its concentration determined colorimetrically using pyridine-barbituric acid.

Thiocyanate

The sodium hydroxide impinger train used for collecting cyanide was also used for analyzing thiocyanate. Thiocyanate was measured on-site by a colorimetric procedure (Ref. 7) in which cupric copper and pyridine react with the thiocyanate to form a green precipitate. The precipitate is extracted with chloroform and measured spectrophotometrically.

Ammonia

Ammonia was collected in 5 percent sulfuric acid using a two-impinger train. Following sampling, the absorbing solutions were cooled to 4°C (39°F) for storage prior to on-site analysis. The samples were analyzed using Standard Methods 418A and 418D (Ref. 6). These methods involve buffering the sample at pH 9.5 and distilling the ammonia into an indicating boric acid solution. The ammonia in the distillate was then titrated with standard sulfuric acid to the lavender end point of the indicator.

Metal Carbonyls (Fe, Ni)

Since no special preservation was required for the iron and nickel carbonyl impinger solutions, those analyses were performed off-site. Ascorbic acid was first used to reduce the iodine present in the I_2/KI acid impinger solutions. The samples were then analyzed for Fe and Ni using atomic absorption. Detection limits were fixed by analyzing the amount of iron or nickel in a reagent blank.

Nitrogen Oxides

EPA reference Method 7 was used to determine the nitrogen oxides concentration in the test burner flue gas. This method involves collecting a gas grab sample in an evacuated glass bomb containing a dilute sulfuric acid/hydrogen peroxide solution. Nitrogen oxides, excluding nitrous oxide, are absorbed in the solution and subsequently quantified using the phenoldisulfonic acid (PDS) procedure.

Total Sulfur

Gas samples for total sulfur determination were bubbled through a five-impinger train to assure complete collection of sulfur species. The first two impingers contained 6 percent hydrogen peroxide, the next two contained 2 N zinc acetate and the last one contained 0.1 N alcoholic potassium hydroxide. The peroxide and potassium hydroxide impingers were analyzed off-site for sulfate by ion chromatography (the potassium hydroxide impingers were treated with peroxide to oxide CS_2 and COS to SO_4^-). The zinc acetate impingers were analyzed on-site for sulfide by the iodine titration method. The sulfur content of each impinger was summed to give total sulfur for the gas stream.

4.1.2 Liquid Phase Analysis

Three samples from the Glen-Gery test program were analyzed for water quality parameters. These samples were ash sluice water, ash leachate, and cyclone dust leachate.

Both the ash and cyclone dust leachate samples were prepared using a modification of the Toxicant Extraction Procedure (TEP). This involved weighing a representative amount of the solid and crushing it to an approximate diameter of 9.5 mm. The solid was then added to approximately eight times its weight of deionized water. The solution was adjusted to pH 5 and the sample was agitated for a period of 24 hours. The modification to the TEP occurred at this point. The TEP stipulates filtering the solution and adjusting the filtrate volume to 20 times the initial weight of the solid sample by addition of deionized water. Instead, the filtrate volume was adjusted to only 10 times the initial sample weight and the remaining solid was re-extracted using the same procedure. The water quality analyses were then performed on the combined extracts (leachates).

Both the TEP and the modified TEP use pH adjustments and result in an extract volume adjusted to 20 times the initial weight of the solid sample. Therefore, both should give comparable results, i.e., same species being leached. However, the modified procedure is equivalent to a 48-hour agitation period instead of the 24-hour period called for by the TEP. For this reason, the modified TEP could be expected to give possibly higher results, i.e., higher concentrations of leached components than if the unmodified TEP had been used.

Since the sample extractions were performed, the suggested solids extraction procedures have been modified. As set forth by the Resource Conservation and Recovery Act (RCRA), the current extraction procedure (EP) differs from the TEP in that there is an upper limit to the amount of acid addition allowed for pH adjustments. However, the amount of acid added for pH adjustments to both the ash and cyclone dust was well within the limit allowed by the current RCRA extraction procedure (EP). Therefore, the results obtained using the modified TEP should also be comparable to (but possibly higher than) the results that would have been obtained if the current RCRA procedures had been used.

The three liquid samples from the Glen-Gery test program were analyzed for water quality parameters according to the methods shown in Table 4-2. The following text describes each analytical procedure.

TABLE 4-2. ANALYTICAL METHODS FOR WATER QUALITY PARAMETERS

Parameter	Method and Reference
Anions:	
Chloride	Titration; Standard Methods (Ref. 6), page 304-306
Cyanide	Distillation, colorimetry; Standard Methods (Ref. 6), page 367-369, 370-372
Fluoride	Specific ion electrode; Standard Methods (Ref. 6), page 391-393
Nitrate	Colorimetry; Standard Methods (Ref. 6), page 429-431
Phosphate	Colorimetry; Standard Methods (Ref. 6), page 476, 481-482
Sulfide	Titration; Standard Methods (Ref. 6), page 505
Sulfate	Ion chromatography (Ref. 8)
Thiocyanate	Colorimetry (Ref. 7)
Ammonia	Distillation, colorimetry; Standard Methods (Ref. 6), page 410-412, 417-418
BOD	Bioassay; Standard Methods (Ref. 6), page 543-549
COD	Oxidation, titration; Standard Methods (Ref. 6), page 550-554
TOC	Combustion-infrared method; Standard Methods (Ref. 6), page 523-534
Residue	Gravimetric method; Standard Methods (Ref. 6), page 89-98

Anions

Chloride - Chloride was determined according to procedures outlined in Standard Methods for the Examination of Water and Waste Water. (Ref. 6) The chloride concentration was measured by titration using a standard silver nitrate solution. The endpoint is detected by using a potassium chromate indicator.

Cyanide - Cyanide was analyzed by the distillation-colorimetry method in which cyanide is distilled from the sample and collected in a sodium hydroxide solution. Colorimetric development occurs with a pyridine-barbituric acid which forms an intense blue color with free cyanide. The resulting absorbance is measured at 578 nm and compared to a set of standard cyanide solutions.

Fluoride - Fluoride was determined by standard addition techniques using a specific ion electrode. Citrate buffer is added to release fluoride complexed by uranium, thorium, aluminum and iron and to cancel out variances in pH and ionic strength. The observed potential change is directly related to fluoride concentration.

Nitrate - Nitrate was determined by a colorimetric method in which nitrate reacts with chromotropic acid to form a yellow reaction product which is measured spectrophotometrically at 410 nm and compared to a set of standards.

Phosphate - Phosphates are digested to the orthophosphate form by boiling with sulfuric acid and ammonium persulfate. The pH is adjusted up to the phenolphthalein end point with sodium hydroxide and the orthophosphate is determined using a colorimetric method. Orthophosphate reacts with ammonium molybdate and potassium antimony tartarate in an acidic medium to form a heteropoly acid, phosphomolybdic acid, which is reduced by ascorbic acid to the highly colored molybdenum blue. The absorbance of the sample is measured at 880 nm and compared to a set of standards.

Sulfide - Sulfides were precipitated as zinc sulfide by adding zinc acetate under alkaline conditions. The precipitate is removed by filtration. The zinc sulfide and the filter are transferred to a flask and an excess of a standard iodine solution is added. The excess iodine is then back titrated with sodium thiosulfate to a starch end point to determine the amount of iodine consumed by the sulfide.

Sulfite and Sulfate (as Sulfate) - The filtrate from the sulfide analysis was used to determine the sulfite and sulfate content of the sample. Sulfite was oxidized to sulfate by the addition of hydrogen peroxide and the sulfate was determined by ion chromatography utilizing a Dionex Model 14 instrument. An exchange resin separates the anions and the sulfate is monitored with a conductivity cell. Retention time and conductivity response are compared with a set of standard solutions to quantify the sulfate.

Thiocyanate - Thiocyanate was determined by a colorimetric procedure in which sulfide is removed by lead sulfide precipitation and the filtrate extracted at pH 3-3.5 with chloroform to remove extractable hydrocarbons. Following this pretreatment the aqueous phase thiocyanate is reacted with cupric copper and pyridine to form dithiocyanateopyride. This light green precipitate is extracted into chloroform and measured spectrophotometrically at 407 nm. Concentration is determined by comparison of absorbance with a set of thiocyanate extracted standards.

Ammonia

Ammonia was determined by a distillation-titration method in which the sample is buffered at pH 9.5 and the ammonia distilled into an indicating boric acid solution. The ammonia in the distillate is titrated with a dilute sulfuric acid standard to the lavender end point of the indicator.

Biochemical Oxygen Demand (BOD)

BOD is a measure of the change in the amount of dissolved oxygen in a sample when incubated in the dark at 20°C for five days. This change in dissolved oxygen is related to the amount of organic matter which is assimilated and oxidized by microorganisms. An initial dissolved oxygen concentration was determined and after five days a final concentration was determined.

Chemical Oxygen Demand (COD)

Chemical oxygen demand was determined by refluxing the sample with potassium dichromate and sulfuric acid for two hours. After cooling, the excess dichromate was titrated with ferrous ammonium sulfate. The amount of potassium dichromate consumed is proportional to the amount of oxidizable matter in the sample.

Total Organic Carbon (TOC)

Samples were analyzed for TOC with a Dorman Model 52/D TOC analyzer using a flame ionization detector to provide linear response up to 200 μg/ml carbon concentration.

Residue (Solids)

Total residue (solids) was determined by evaporating an aliquot of sample to a constant weight at 103-105°C. For determination of total dissolved solids and total suspended solids, the sample was filtered through a fine glass fiber filter. The filtrate was evaporated for dissolved solids, while the filter catch was weighed to determine suspended solids.

4.1.3 Solid Phase Analysis

Solid samples collected during the Glen-Gery test program included coal feedstock, dry ash, and cyclone dust. In addition, solids analyses were performed on samples of the particulates entrained in the gasifier inlet air and in the product low-Btu gas.

Physical analyses, size distribution, specific gravity and particle morphology were performed by Radian Corporation. For many of the samples, a size distribution could not be determined because of the large particle sizes. Hazen Research, Inc. was contracted to perform gross α and β analyses on selected samples. Proximate and ultimate analyses of coal, dry ash and cyclone dust samples were done by Commercial Testing and Engineering Co. using standard procedures.

4.1.4 Analyses for Trace Elements

Trace element analyses were performed on all of the streams sampled except the coal hopper gas (see Table 4-3). Liquid samples (including impinger solutions) were analyzed without modification. Solid samples were first ashed in a quartz-lined Parr combustion bomb, and then dissolved in dilute aqueous nitric acid. The resultant liquid samples were then analyzed without modification.

Analyses for the volatile trace elements - mercury, antimony, and arsenic - were performed at Radian using atomic absorption spectrophotometry. Analyses for the remaining elements were by spark source mass spectrometry, performed by Commercial Testing and Engineering Laboratories, Golden, Colorado. Blank samples were also run on the Parr bomb itself and on clean XAD-2 resin samples.

4.2 ORGANIC ANALYSIS

The organic analyses for the Glen-Gery test program involved light hydrocarbons and extractable organics analyses. Gas grab samples of the product low-Btu gas, coal hopper gas and test burner flue gas were analyzed by on-site gas chromatographs for light hydrocarbons. Samples of the following streams were extracted, prepared and analyzed for extractable organics.

- Product gas.
- Test burner flue gas.
- Ash.
- Cyclone dust.
- Gasifier inlet air particulates.
- Ash leachate.
- Ash sluice water.
- Cyclone dust leachate.

TABLE 4-3. SAMPLES ANALYZED FOR TRACE ELEMENT COMPOSITION

Coal Feed
Ash Sluice Water
Dry Ash
Ash Leachate
Cyclone Dust
Cyclone Dust Leachate
Particulates in Gasifier Inlet Air
Jacket Water
Service Water
Product Low-Btu Gas
Particulates in Product Low-Btu Gas
Test Burner Flue Gas

4.2.1 Light Hydrocarbons

Grab samples from each of the three gas streams sampled were collected in flexible teflon bags and analyzed for light hydrocarbon content (C_1 through C_6). The analyses were made using a Hewlett-Packard Model 5630 gas chromatograph equipped with a flame ionization detector (FID). Five milliliter aliquots of the gas samples were injected directly onto the column using a gas-tight syringe. Instrument operating conditions for this analysis are given below.

Column: 6' x 1/8" stainless steel, Poropak Q
100/120, mesh

Carrier Gas: N_2

Carrier Flow: 40 cm^3/min

Injector Temp: 150°C

Detector Temp: 200°C

Oven Program: 40°C for 8 min.
8°/min to 220°C
220°C for 4 min.

The detector output was recorded on a Hewlett-Packard Model 3380A Integrator/Plotter. Component concentrations were determined from peak areas as calculated by the integrator.

The integrator was calibrated by analyzing a standard mixture of methane, ethane, propane, n-butane, n-pentane, and n-hexane in nitrogen. This calibration was performed daily before the first sample was run.

4.2.2 Organic Extraction Procedures

In this section, the procedures used to obtain extractable organic samples from process and waste streams are presented. Samples of the following streams were collected for analysis:

- Gaseous streams (product gas, test burner flue gas and gasifier inlet air),
- Solid waste streams (ash and cyclone dust), and
- Liquid streams (ash and cyclone dust leachates and ash sluice water).

Three different extraction procedures were used on the samples, as shown in Table 4-4. Some samples were extracted with diethylether at pH 12 for 36 hours and then at pH 1 for 36 hours. Other samples were extracted with methylene chloride for 36 hours in a Soxhlet extraction apparatus. The gasifier wet ash was extracted with diethylether for 36 hours and then with methylene chloride for 36 hours. The extraction procedures used for each sample are shown in Table 4-4. Generally, when more than one sample of a stream was extracted, all the extracts were combined for analysis. The extract of the product gas particulates was analyzed individually.

4.2.3 Preparation and Analytical Methods for Organic Extracts

All extracts were dried 24 hours over Na_2SO_4 and then filtered through clean glass filters. The solutions were then concentrated to approximately 5 ml or to the point of precipitate appearance using a Kuderna-Danish concentration apparatus.

The samples were concentrated and the following analytical procedures were used:

- Gravimetric analysis,
- Total chromatographable organics (TCO) analysis, and
- Gas chromatography/mass spectrometry analysis.

These techniques are discussed in the following sections.

TABLE 4-4. SUMMARY OF EXTRACTION PROCEDURES USED IN THE GLEN-GERY TEST PROGRAM

Sample	Extraction Procedure	Remarks
Product Gas (SASS Train):		
probe and organic module rinses	None	Combine rinses and extracts (except particulates) into one sample for analysis.
condensate	$(C_2H_5)_2O$*	
XAD-2 resin	CH_2Cl_2**	
particulates	CH_2Cl_2**	
Combustion Gas (SASS Train):		
probe and organic module rinses	None	Combine rinses and extracts into one sample for analysis.
condensate	$(C_2H_5)_2O$*	
XAD-2 resin	CH_2Cl_2**	
Inlet Air (Hi-Vol Slipstream):		
XAD-2 resin	CH_2Cl_2**	
Wet Ash	$(C_2H_5)_2O$*** CH_2Cl_2**	Combine extracts into one sample for analysis.
Dry Ash	CH_2Cl_2**	
Cyclone Dust	CH_2Cl_2**	
Ash Leachate	$(C_2H_5)_2O$*	
Cyclone Dust Leachate	$(C_2H_5)_2O$*	
Ash Quench Water	$(C_2H_5)_2O$*	

*Extraction with diethylether at pH 12 for 36 hours and then at pH 1 for 36 hours.

**Extraction with methylene chloride for 36 hours in a Soxhlet extraction apparatus.

***Extraction with diethylether for 36 hours.

Gravimetric Analysis

Gravimetric analyses (GRAV) were performed by transferring 1-4 ml of the concentrated extracts to a tared aluminum weighing pan. The solvent was allowed to evaporate until a constant weight was achieved. The sample was weighed at 4-hour intervals using a Mettler H51 analytical balance. The sample was protected from dust and other contamination by placing it in a glass petri dish and storing it in a dessicator.

Total Chromatographable Organics Analyses

Total chromatographable organics (TCO) are defined as those compounds which have gas chromatographic retention times between n-heptane and n-hexadecane. TCO analyses were carried out on a Tracor Model 560 gas chromatograph equipped with a flame ionization detector. Integrations and baseline corrections were carried out on a Spectra Physics SP4000 Central Processor equipped with disc memory. Five to twenty µℓ samples were injected by syringe and analyzed. The analyses were performed under the following instrument conditions:

Column: 6' x 2 mm i.d. glass, 10% OV-101 on
100-120 mesh Supelcoport

Carrier Gas: N_2

Carrier Flow: 30 cm^3/min

Oven Program: 30°C for 4 min
16°C/min to 250°C
250°C until after elution time of C_{17} standard, then an additional 5 min

Injector Temp: 250°C

Detector Temp: 250°C

Calibrations were performed daily using a methylene chloride solution containing 342-389 µg/ml of the normal alkanes from C_6 through C_{17}.

Gas Chromatography/Mass Spectrometry Analysis

The concentrated extracts were analyzed by a Hewlett-Packard 5985 Gas Chromatography/Mass Spectrometry (GC/MS) System. A portion of each extract was injected onto a six-foot SP-2250 packed glass column. After an initial hold at 50°C for four minutes, the column was temperature programmed to 260°C at 8°C/minute. The organic species which eluted from the gas chromatograph were transferred to the ion source of the mass spectrometer by means of a glass jet separator. The mass spectrometer was scanned continuously from m/e 50 to m/e 450 with a cycle time of three seconds. Electron impact (70 eV) ionization was employed exclusively for the analyses. The mass spectral information was stored on a magnetic disc for future interpretation and reference.

Identification of selected organic species was performed by a technique known as selected ion current profiles (SICP) search. This technique is based on the appearance of key ions within a narrow retention time window and is used to search for certain compounds, especially polynuclear aromatic hydrocarbons. In addition, interpretation of mass spectra was performed by comparison of the unknown mass spectrum against the mass spectrum of a previously analyzed standard. Table 4-5 lists the organic species selected for the SICP search.

Semi-quantitative analysis of the identified compounds was achieved by measuring the area under the SICP for each compound. For a given compound, the area under the most abundant ion was calculated using the data system. The computed area was then compared against the area found from the most abundant ion of the internal standard, d_{10}-anthracene. The concentration of the species was then calculated using the following equation:

$$C = \frac{Ac \times Ca}{Aa \times R} \quad \text{where,}$$

C = the concentration of the component,

Ac = the integrated area of the characteristic ion from the selected ion current profile,

R = the response factor for this component relative to deuteroanthracene,

Aa = the integrated area of the characteristic ion for d_{10}-anthracene, and

TABLE 4-5. LIST OF SELECTED ORGANIC SPECIES FOR SELECTED ION CURRENT PROFILES SEARCH

MEG Category	Compound
2A. Saturated Alkyl Halides	Hexachloroethane
2B. Unsaturated Alkyl Halides	Hexachlorobutadiene Hexachlorocyclopentadiene
4. Halogenated Ethers	Bis (2-Chloroethyl) Ether Bis (2-Chloroethoxy) Methane Bis (2-Chloroisopropyl) Ether 4-Bromophenyl Phenyl Ether 4-Chlorophenyl Phenyl Ether
7B. Ketones	Isophorone
8D. Esters	Bis (2-Ethylhexyl) Phthalate Butyl Benzyl Phthalate Di-N-Butyl Phthalate Diethyl Phthalate Dimethyl Phthalate Di-N-Octyl Phthalate
11. Azo Compounds: Hydrazine Derivatives	1, 2-Diphenyl Hydrazine
12. Nitrosamines	N-Nitroso Dimethylamine N-Nitroso Diphenylamine N-Nitroso Di-N-Propyl Amine
16A. Ring Substituted Halogenated Aromatics	Benzidine (4, 4 Diamino Diphenyl) 2-Chloronaphthalene 1, 2-Dichlorobenzene 1, 3 and 1, 4-Dichlorobenzene 3, 3-Dichlorobenzidine Hexachlorobenzene 1, 2, 4-Trichlorobenzene
17. Aromatic Nitro Compounds	Nitrobenzene 2, 4-Dinitrotoluene 2, 6-Dinitrotoluene
21. Fused Polycyclic Hydrocarbons	Acenaphthene Acenaphthylene Benzo (G, H, I) Perylene Benzo (A) Pyrene Chrys and Benz (A) Anthracene Dibenzo (A, H) Anthracene Indeno (1, 2, 3-C, D) Pyrene Naphthalene Phenanthrene and Anthracene Pyrene
22. Fused Non-Alternant Polycyclic Hydrocarbons	Benz (B & K) Fluoranthene Fluoranthene Fluorene

Ca = the concentration of deuteroanthracene in
the extract.

Radian has previously determined response factors for many compounds relative to d_{10}-anthracene. Where the response factor was not known, a value of 1.0 was employed.

In addition to the organic compounds listed in Table 4-5, the concentrations of S_8 and low molecular weight phenols in the organic extracts were determined.

4.3 BIOASSAY ANALYSIS

Selected samples obtained during the Glen-Gery test program were subjected to various bioassay screening tests. The analyses consisted of three health effect tests and one ecological test. The test and the company or institute that performed them are listed below.

- Health Effect Tests (Arthur D. Little)
  - Ames
  - Cytotoxicity (WI-38, RAM)
  - Rodent acute toxicity
- Ecological Effects Test (Battelle)
  - Terrestrial (soil microcosm)

The procedures for each of the above tests are described in the EPA Level 1 Environmental Assessment Manual (Ref. 5). The following text presents a brief description of the methodologies used to perform the tests.

4.3.1 Ames Test

The Ames test is used to measure the potential mutagenicity (carcinogenicity) of a material. This test was performed on the following samples:

- Coal feed,
- Particulates in product gas, >3μ
- Particulates in product gas, <3μ
- Coal ash,
- Ash leachate,
- Ash sluice water,
- Cyclone dust,
- Cyclone dust leachate,
- Particulates in test burner flue gas,
- Product gas organic extract, and
- Test burner flue gas organic extract.

The Ames test performed on the above samples used Salmonella typhimurium strains TA1535, TA1537, TA1538, TA98 and TA100. These strains were all histidine auxotrophs. Strains TA98 and TA100 are not specified in the Level 1 procedure, however, in some cases they are more sensitive to mutagenic agents. The Ames test has been proven to be 80 to 90% accurate in detecting carcinogens as mutagens, and it has about the same accuracy in identifying materials that are not carcinogenic. Therefore, neither a positive or negative response proves conclusively that a material is hazardous or nonhazardous to man.

4.3.2 Cytotoxicity Tests

Cytotoxicity tests are used to estimate the acute cellular toxicity of a sample from an in-vitro cell mortality test using a human lung culture (WI-38) and rabbit aveolar macrophases (RAM). These tests were performed on the following samples:

- Coal feed (RAM),
- Gasifier ash (RAM),
- Ash leachate (WI-38),

- Ash sluice water (WI-38),
- Cyclone dust (RAM), and
- Cyclone dust leachate (WI-38).

The protocol defined in the Level 1 Environmental Assessment Manual (Ref. 5) was used. The results of the cytotoxicity test are presented as cell count EC_{50}'s.

4.3.3 Rodent Acute Toxicity Test

The rodent acute toxicity test is used to measure the acute toxicity of a material in a whole animal by administering known levels of the sample to a small population of rats. Samples analyzed by this test were:

- Coal feed,
- Gasifier ash,
- Ash leachate,
- Ash sluice water, and
- Cyclone dust.

Young adult albino Sprague-Dawley rats (weighing approximately 250 g at the time of treatment) were used. The sample was administered to the test rats (5 male and 5 female) in a single dose of 10 g of sample per kg of animal weight. The rats were observed frequently, and were weighed daily. Necropsies were performed on the animals that survived 14 days.

4.3.4 Soil Microcosm Test

The soil microcosm test is used to measure or rank the toxicity of a material to the microorganisms found in soil. The samples that were tested were:

- Gasifier ash, and
- Cyclone dust.

Measurements on CO_2 efflux and calcium export were made. The results of these analyses were used to rank the samples according to their soil microcosm toxicity. Dissolved organic carbon measurements were not made on these samples.

4.4 PROCESS GAS CHROMATOGRAPH ANALYSES

On-line process gas chromatographs (GC's) were used to continuously monitor the product low-Btu gas for eleven selected compounds. The instruments used were Applied Automation Model 102 Chromatographs equipped with various detectors. The three detectors used and the species detected by each are listed below:

Detector Unit	Species Detected
Flame Ionization Detector (FID)	CH_4, C_2H_4, C_2H_4, C_2H_6, C_3H_6, C_3H_8, and C_4+ hydrocarbons
Flame Photometric Detector (FPD)	COS, H_2S, CS_2, SO_2
Filament/Thermal Conductivity Detector (TCD)	NH_3

The operating specifications for the process GC's are summarized in Table 4-6. Outputs from the three detectors were recorded on strip charts and also stored in DOE's on-site data acquisition system.

Samples for the process GC's were obtained through a 9.5 mm (3/8 in) diameter stainless steel line extending 5 cm (2 in) into the 51 cm (20 in) product gas line. Particulates were removed from the gas sample by an insulated Balston filter. From the filter, the gas sample was transported through a 6.4 mm (1/4 in) stainless steel sample line to a sample gas conditioning system. The sample line was maintained at approximately 200°C (392°F) by heat tracing. The sample conditioning system was maintained at 138 to 148°C (280 to 300°F). After flowing through a perma pure drier to remove moisture, the product gas samples were directed to the appropriate gas chromatograph unit.

TABLE 4-6. OPERATING SPECIFICATION FOR ON-LINE PROCESS GAS CHROMATOGRAPHS AT THE GLEN-GERY FACILITY

Chromatograph Detector Unit	Compound Detected	Temp. (F°)	Cycle Time, (Minutes)	Column
FPD	COS, H_2S, CS_2, SO_2	285	4.0	.30 m (1 ft) of 3.2 mm (1/8 in) Teflon w/40% Carbowax on Chromosorb P (80/100 Mesh) and 3.7 m (12 ft) of 3.2 mm (1/9 in) Teflon with 1% TCEP on Porasil B (80/100 Mesh)
FID	CH_4, C_2H_6, C_2H_4, C_3H_8, C_3H_6, C_4+	285	7.5	.60 m (2 ft) of 3.2 mm (1/8 in) SS with Porapak T (80/100 Mesh), 4.3 m (14 ft) of 3.2 mm (1/8 in) SS with Porasil A (80/100 Mesh), and .30 m (1 ft) of 3.2 mm (1/8 in) SS with Chromosorb G (80/100 Mesh)
TCD	NH_3	285	8.25	1.5 m (5 ft) of 3.2 mm (1/8 in) SS with 1% Polyethylene Imine on Porapak T (80/100 Mesh) and 4.6 m (15 ft) of 3.2 mm (1/8 in) SS with 1% Polyethylene Imine on Porapak T (80/100 Mesh)

FPD = Flame Photometric Detector
FID = Flame Ionization Detector
TCD = Thermal Conductivity Detector

SECTION 5.0

TEST RESULTS

The source test and evaluation (STE) program for the Wellman-Galusha gasification facility at the Glen-Gery Brick Co. was designed to meet three major objectives:

- perform an environmental assessment of the waste streams,
- characterize the performance of the product gas cyclone, and
- characterize the flue gas resulting from the combustion of the low-Btu product gas.

The test results of the STE program are presented in this section. Two methods were used to assess the environmental characteristics of the facility's waste streams: SAM/1A evaluation of the chemical test results and bioassay analyses. These two evaluation methods are discussed in Section 5.1. Section 5.2 contains the chemical and biological test results for each waste stream and the evaluation of that data. The results of the cyclone characterization and the low-Btu gas combustion tests are presented in Sections 5.3 and 5.4, respectively.

5.1 METHODS OF EVALUATING WASTE STREAM CHARACTERISTICS

Two methods were used to evaluate the characteristics of the waste streams from the Glen-Gery gasification facility:

- SAM/1A evaluation, and
- bioassay screening tests.

5.1.1 SAM/1A Evaluation

The Energy Assessment and Control Division of the EPA's Industrial Environmental Research Laboratory at Research Triangle Park (EACD/IERL-RTP) has developed a standardized methodology for interpreting the results obtained from environmental assessment test programs. This methodology uses Source Analysis Models (SAM's) (Ref. 9).

The simplest member of the Source Analysis Models, SAM/1A, was used for this STE program. SAM/1A provides a rapid screening technique for evaluating the pollution potential of gaseous, liquid, and solid waste streams. In performing a SAM/1A evaluation, two types of evaluation indices are calculated: Discharge Severity (DS) and Weighted Discharge Severity (WDS).

DS is calculated by dividing the detected concentration of a compound, or class of compounds, by its Discharge Multimedia Environmental Goal (DMEG) value (for both health and ecological effects) as reported in the Multimedia Environmental Goals (MEG's) (Ref.10). A DS value greater than one indicates a potential hazard, while a value less than one indicates little or no potential hazard. A total stream discharge severity (TDS) is calculated by summing the DS's for all constituents found in a sample.

The Weighted Discharge Severity is calculated by multiplying the TDS by stream flow rate. Because WDS's incorporate stream flow rate data, they are useful indices for ranking the waste streams from a facility in terms of their potential hazard.

There are several assumptions implicit in the use of the SAM/1A evaluation technique. The major assumptions include:

- The substances currently in the MEG's are the only ones that must be addressed at this time. The January 1979 updated MEG list was used for organic compounds.
- Transport of the components in the waste streams to the external environment occurs without chemical or physical transformation of those components.
- Actual dispersion of a pollutant from a source to a receptor will be equal to, or greater than, the safety factors normally applied to acute toxicity data to convert these data to estimated safe chronic exposure levels.

- The DMEG values developed for each substance are adequate for estimating acute toxicity.
- No synergistic effects occur among the waste stream components.

These assumptions, along with the accuracy of the test data and assumptions used in developing DMEG values (Ref. 10), must be considered when interpreting test results using the SAM/1A methodology. It should be noted that, based on updated information from Research Triangle Institute, the ecological DMEG values should be two orders of magnitude higher than the values reported in the November 1977 Multimedia Environmental Goals for Environmental Assessment publication. The higher values were used in the SAM/1A evaluation.

Results of both inorganic and organic analyses were evaluated using SAM/1A. The inorganic data were obtained from trace element, water quality and gaseous species analyses. The total concentration of organic extractables in each sample was obtained from gravimetric (GRAV) and total chromatographable organics (TCO) determinations. Specific organic compounds were identified and quantified using gas chromatography/mass spectrometry (GC/MS). However, the GC/MS analyses did not identify all of the organics that were indicated to be present by the GRAV and TCO determinations. For the identified organics, DS values were developed using the procedures defined previously. To estimate the potential hazard of the unidentified organics, a worst case approach was used.

The intent of the worst case evaluation was to calculate a hypothetical DS for the unidentified organics. This was accomplished by screening the organic MEG categories in order to select the most hazardous compound in each category. Then a hypothetical DS was calculated for each category by assuming that the unidentified organics consisted entirely of the most hazardous compound in that category. Finally, the resulting hypothetical DS's were compared and the largest value used as the worst case hypothetical DS. This value was in turn combined with the DS's for the identified compounds to give the total stream discharge severity (TDS).

The procedures used to select the most hazardous compound in each MEG category incorporated several assumptions, as indicated on the following page:

- compounds that would have been, but were not, identified by GC/MS analysis need not be considered,
- the compound in each MEG category with the lowest DMEG value represents the worst case compound for that MEG category,
- based on results from previous gasification test programs, chlorinated organics are not likely to be present in the waste streams, and
- organics with a boiling point less than 100°C are not included in the unidentified organics.

Figure 5-1 illustrates the process used to select the worst case compound in each MEG category.

5.1.2 Bioassay Test Analysis

The results reported for the bioassay tests were derived from the reports submitted by subcontractors performing the tests. The bioassay tests were performed in accordance with Level 1 environmental assessment procedures (Ref. 5). Comparisons were made between the bioassay test results and the SAM/1A evaluation of the chemical analytical results.

5.2 CHEMICAL AND BIOLOGICAL TEST RESULTS

The chemical and biological test results from the STE program at the Glen-Gery gasification facility are presented in the following sections:

- total plant,
- gaseous waste streams,
- liquid waste streams,
- solid waste streams, and
- additional chemical test results.

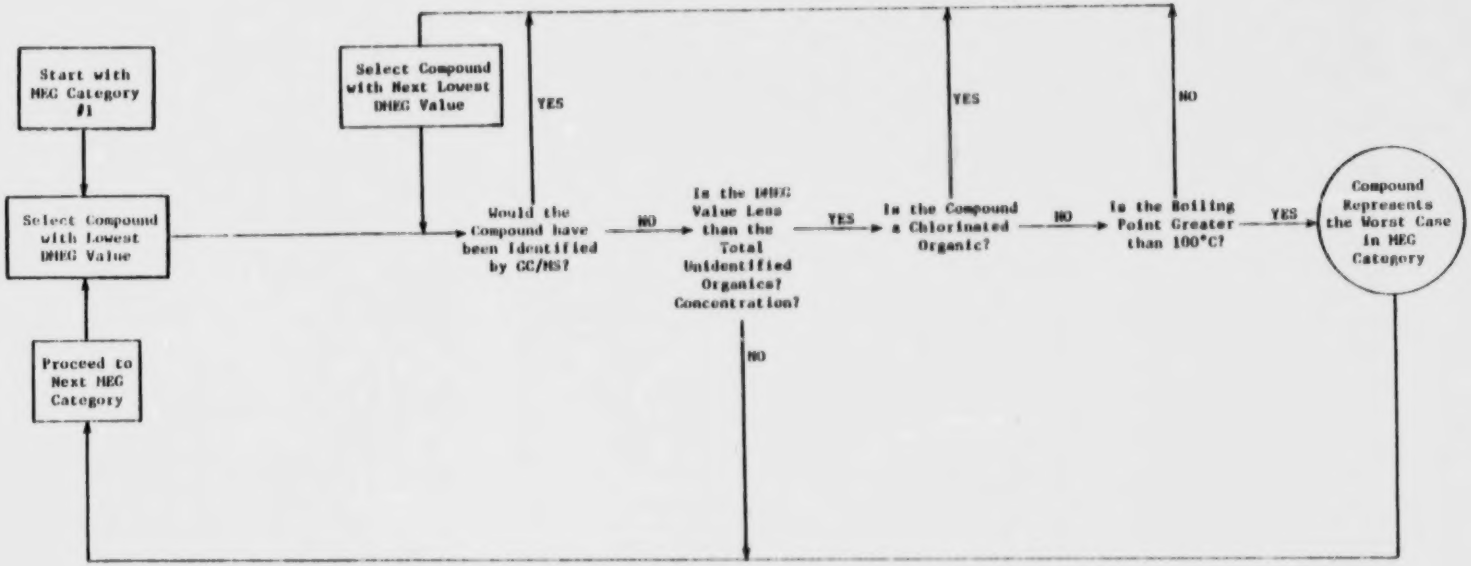

Start with MEG Category #1
Select Compound with Lowest DMEG Value
Proceed to Next MEG Category
Select Compound with Next Lowest DMEG Value
Would the Compound have been Identified by GC/MS?
YES
NO
Is the DMEG Value Less than the Total Unidentified Organics? Concentration?
YES
NO
Is the Compound a Chlorinated Organic?
YES
NO
Is the Boiling Point Greater than 100°C?
NO
YES
Compound Represents the Worst Case in MEG Category

Figure 5-1. SELECTION OF WORST CASE COMPOUNDS FOR SAM/1A EVALUATION OF UNIDENTIFIED ORGANICS

5.2.1 Total Plant

The total plant test results are presented as a material balance around the entire plant and a summary of the bioassay test results and SAM/1A evaluation of waste streams. The material balance around the facility (see Table 5-1) was calculated by monitoring the flow rates and composition of the major inlet and outlet process streams over a 96-hour period, as described in Section 2.2. The gasification facility operated at full capacity during this time period except for a 7-hour emergency shutdown caused by a mechanical failure.

There were three types of waste streams at the Glen-Gery facility: gaseous, liquid and solid. Tables 5-2, 5-3, and 5-4 summarize the SAM/1A evaluation and bioassay test results for the waste streams sampled. The contribution of inorganic, identified organic compounds, and unidentified organic compounds to the total waste stream discharge severity (TDS) and weighted discharge severity (WDS) are presented.

All of the waste streams sampled contained constituents in potentially hazardous concentrations. This is indicated by the TDS's which ranged from 47 to 12,000. While greater than one, the DS's shown in Tables 5-2 through 5-4 are generally significantly less than those calculated for similar waste streams from a gasification facility using bituminous coal (Ref. 1). The low hazard potential for the Glen-Gery waste streams is also supported by the results of the bioassay screening tests.

5.2.2 Gaseous Waste Streams

The gaseous waste streams that were sampled at the Glen-Gery facility were the pokehole gas and coal hopper gas. Fixed gases, sulfur species, light hydrocarbons, and trace element analyses were performed for SAM/1A evaluation. Bioassay tests were not performed on the gaseous waste streams. The following text discusses the results of the chemical analyses and the SAM/1A evaluation of those test results.

Pokehole Gas -

The small flow rate of the pokehole gas prevented collection of an adequate quantity of sample for chemical analysis.

TABLE 5-1. AVERAGE COMPOSITIONS OF MAJOR PROCESS STREAMS AT THE GLEN-GERY GASIFICATION FACILITY

Component	Coal	Inlet Air*	Gasifier Ash	Cyclone Dust	Coal Hopper Gas*	Product Gas*
Ash - wt. %	11.7 (±10%)		65.8 (±10%)	24.7 (±10%)		
Carbon - wt. %	81.2 (±10%)		33.0 (±10%)	70.1 (±10%)		
CO_2 - vol. %		0.02 (±100%)			4.6 (±6%)	5.5 (±5%)
CO - vol. %					23.6 (±11%)	25.5 (±7%)
CH_4 - vol. %					0.22 (±12%)	0.23 (±17%)
Nitrogen - wt. %	0.82 (±8%)		0.18 (±8%)	0.62 (±8%)		
N_2 - vol. %		79 (±2%)			54.1 (±4%)	51.6 (±1%)
Oxygen - wt. %	2.6 (±10%)		0.30 (±10%)	0.95 (±10%)		
O_2 - vol. %		21 (±10%)			3.0 (±70%)	0.90 (±20%)
H_2O - wt. %	0.94 (±10%)		0.25 (±10%)	0.71 (±10%)		
H_2O - vol. %		23 (±15%)			5.9 (±100%)	5.9 (±10%)
Hydrogen - wt. %	2.14 (±10%)		0.27 (±10%)	1.4 (±10%)		
H_2 - vol. %					14.5 (±15%)	16.3 (±4%)
Sulfur - wt. %	0.62 (±10%)		0.20 (±10%)	1.5 (±10%)		
H_2S - vppm					290 (±22%)	690 (±22%)
COS - vppm					60 (±19%)	93 (±19%)
SO_2 - vppm					5 (±250%)	21 (±250%)
CS_2 - vppm					<0.5	0.8 (±80%)

* All gas compositions on a dry gas basis except moisture content.

Note: The numbers in parenthesis represent the 95% confidence interval for the data.

TABLE 5-2. SUMMARY OF SAM/1A AND BIOASSAY RESULTS FOR GASEOUS WASTE STREAMS FROM THE GLEN-GERY FACILITY

	Discharge Severity[a]		Weighted Discharge Severity[b]		Bioassay Tests	
	Health	Ecological	Health	Ecological	Health[c]	Ecological[d]
Pokehole Gas						
Inorganics and Identified Organics	7.1×10^3	2.7×10^3	1.2×10^1	4.5		
Unidentified Organics	NC	NC				
TOTAL	7.1×10^3	2.7×10^3	1.2×10^1	4.5	NC	NC
Coal Hopper Gas						
Inorganics and Identified Organics	6.9×10^3	2.2×10^3	1.5×10^1	4.8		
Unidentified Organics	NC	NC				
TOTAL	6.9×10^3	2.2×10^3	1.5×10^1	4.8	NC	NC

[a] Discharge Severity (DS) is defined as the ratio of a pollutant's concentration in a stream to its Discharge Multimedia Environmental Goal (DMEG) value.

[b] Weighted Discharge Severity is determined by multiplying the DS value by the waste stream flow rate (gases: Nm^3/sec, liquids: ℓ/sec, solids: g/sec).

[c] Health tests included: Ames, Cytotoxicity (WI-38, RAM), Rodent Acute Toxicity.

[d] Ecological tests included: Soil microcosm.

NC - Test not conducted.

TABLE 5-3. SUMMARY OF SAM/1A AND BIOASSAY RESULTS FOR THE LIQUID WASTE STREAM FROM THE GLEN-GERY FACILITY

	Discharge Severity[a]		Weighted Discharge Severity[b]		Bioassay Tests	
	Health	Ecological	Health	Ecological	Health[c]	Ecological[d]
Ash Sluice Water						
Inorganics and Identified Organics	1.5×10^1	8.7×10^1				
Unidentified Organics*	1.2×10^4*	4.7×10^2*				
TOTAL	1.2×10^4	5.6×10^2	ND	ND	Low	NC

[a] Discharge Severity (DS) is defined as the ratio of a pollutant's concentration in a stream to its Discharge Multimedia Environmental Goal (DMEG) value.

[b] Weighted Discharge Severity is determined by multiplying the DS value by the waste stream flow rate (gases: Nm^3/sec, liquids: ℓ/sec, liquids: ℓ/sec, solids: g/sec).

[c] Health tests included: Ames, Cytotoxicity (WI-38, RAM), Rodent Acute Toxicity

[d] Ecological tests included: Soil microcosm.

NC - Test not conducted.

ND - Flows not determined for potential fugitive emissions or effluents.

*The representative worst case compound used for the ash sluice water are:

Health	Ecological
Fused Polycyclic Hydrocarbons (7, 12 Dimethyl benz(a)anthracene)	Alkenes, Cyclic Alkenes, Dienes (Dicyclopentadiene), and Nitrophenols

TABLE 5-4. SUMMARY OF SAM/1A AND BIOASSAY RESULTS FOR SOLID WASTE STREAMS AND THEIR LEACHATES FROM THE GLEN-GERY FACILITY

	Discharge Severity[a]		Weighted Discharge Severity[b]		Bioassay Tests	
	Health	Ecological	Health	Ecological	Health[c]	Ecological[d]
Ash						
Inorganics and Identified Organics	1.7×10^3	1.1×10^2	7.2×10^4	4.8×10^3		
Unidentified Organics*	4.9×10^1*	1.9*	2.1×10^3*	8.1×10^1*		
TOTAL	1.7×10^3	1.1×10^2	7.4×10^4	4.8×10^3	Low	e
Ash Leachate						
Inorganics and Identified Organics	6.8×10^{-1}	1.1×10^2				
Unidentified Organics*	9.3×10^3*	3.6×10^2*				
TOTAL	9.3×10^3	4.7×10^2	ND	ND	Low	NC
Cyclone Dust						
Inorganics and Identified Organics	3.0×10^3	2.2×10^2	1.1×10^3	8.2×10^1		
Unidentified Organics*	8.0×10^2*	3.1×10^1*	3.0×10^2*	1.2×10^1*		
TOTAL	3.8×10^3	2.5×10^2	1.4×10^3	9.4×10^1	Low	e
Cyclone Dust Leachate						
Inorganics	4.7×10^1	2.3×10^2				
Unidentified Organics*	1.4×10^3	5.0×10^1*				
TOTAL	1.4×10^3	2.8×10^2	ND	ND	Low	NC

[a] Discharge Severity (DS) is defined as the ratio of a pollutant's concentration in a stream to its Discharge Multimedia Environmental Goal (DMEG) value.

[b] Weighted Discharge Severity is determined by multiplying the DS value by the waste stream flow rate (gases: Nm^3/sec, liquids: ℓ/sec, solids: g/sec).

[c] Health tests included: Ames, Cytotoxicity (WI-38, RAM), Rodent Acute Toxicity

[d] Ecological tests included: Soil microcosm.

[e] The soil microcosm test results cannot be interpreted in terms of a high, medium or low potential for hazard.

NC - Test not conducted.

ND - Flows not determined for potential fugitive emissions or effluents.

*The representative worst case compounds are:

Health	Ecological
Fused Polycyclic Hydrocarbons (7, 12-Dimethyl benz(a)anthracene)	Alkenes, Cyclic Alkenes, Dienes (Dicyclopentadiene) Aromatic Amines and Diamines (Benzidine, Amino napthalenes), Ring Substituted Aromatics (Dibromobenzene), Nitrophenols (Dinitrophenols)

Instead, the composition of the pokehole gas was assumed to consist of the noncondensable (b.p. <100°C) components of the product gas. This is a reasonable assumption, since the pokehole gas cools to approximately 100°C as it escapes directly from the gasifier.

The estimated concentration of organic and inorganic compounds and their corresponding DS values are listed in Table 5-5. As indicated, the health based and ecological based TDS's in the pokehole gas are approximately 7,000 and 3,000, respectively. The major compounds contributing to the health based and ecological based TDS's are CO and ammonia. No organic compounds were major contributors. The major contributors to the total stream discharge severity are summarized in Table 5-6.

Coal Hopper Gas -

The coal hopper gas was analyzed for light hydrocarbons, fixed gases, sulfur species, iron and nickel carbonyls, NH_3, and cyanides. However, nickel carbonyl, NH_3, and cyanides were not found in detectable concentrations. Bioassay analyses were not performed on the coal hopper gas.

Table 5-7 summarizes the SAM/1A evaluation of organic and inorganic test results. The health based and ecological based TDS's are 6900 and 2200, respectively. The major contributors to the health based TDS are CO and $Fe(CO)_5$. CO is the only contributor to the ecological based TDS. Table 5-8 summarizes the major contributors to the TDS.

5.2.3 Liquid Waste Streams

The ash sluice water was the only liquid waste stream sampled from the Glen-Gery facility. Trace elements, water quality and extractable organics were analyzed and bioassay tests were performed on the ash sluice water.

Gravimetric and TCO measurements of the ash sluice water indicate a total extractable content of 46,540 $\mu g/\ell$. GC/MS analysis identified 40 $\mu g/\ell$ of the total extractables as phthalate esters. The remaining 46,500 $\mu g/\ell$ of extractables were not identified.

TABLE 5-5. SUMMARY OF TEST RESULTS AND DISCHARGE SEVERITY VALUES FOR POKEHOLE GAS

MEG Category	Estimated Concentration ($\mu g/m^3$ @ 25°C)	Discharge Severity (Estimated Conc/DMEG Conc) Health	Ecological
1. Methane	1.3×10^6	4.1^a	N
1. Ethane	3.8×10^2	6.2×10^{-5a}	N
1. Propane	7.8×10^3	8.6×10^{-4a}	N
38. Aluminum			
47. Ammonia	1.3×10^5	7.1^a	3.7×10^{2i}
47. Ammonium			
50. Antimony			
49. Arsenic	5.2×10^1	2.6×10^{1f}	N
36. Barium			
32. Beryllium			
51. Bismuth			
37. Boron			
58. Bromide			
82. Cadmium			
34. Calcium			
Carbon			
42. Carbon Dioxide	9.6×10^7	1.1×10^{1a}	N
42. Carbon Monoxide	2.8×10^6	7.0×10^{3f}	2.3×10^3
84. Cerium			
31. Cesium			
57. Chloride			
68. Chromium			
74. Cobalt			
78. Copper			
84. Dysprosium			
Erbium			
Europium			
56. Fluoride			
Gadolinium			
39. Gallium	1.1×10^4	2.0×10^{-3a}	N
44. Germanium			
80. Gold			
64. Hafnium			
Holmium			
59. Iodide			
Iridium			
72. Iron	8.2×10^1	1.2×10^{-1}	N
72. Iron Carbonyl			
84. Lanthanum			
46. Lead			
27. Lithium	5.2×10^1	2.3^a	N
Lutetium			
33. Magnesium			
71. Manganese			
83. Mercury			
69. Molybdenum			
84. Neodymium			
76. Nickel	2.2×10^1	1.4^f	N
76. Nickel Carbonyl	2.9×10^1	6.7×10^{-1f}	N
66. Niobium			
Nitrogen			
47. Hydrogen Cyanide	3.6×10^4	3.3^a	1.1^i
47. Nitrate			
47. Nitrite			
53. Thiocyanate	2.0×10^5	N	N
Osmium			
Palladium			
48. Phosphorus			

TABLE 5-5. CONTINUED

MEG Category	Estimated Concentration ($\mu g/m^3$ @ 25°C)	Discharge Severity (Estimated Conc/DMEG Conc) Health	Discharge Severity (Estimated Conc/DMEG Conc) Ecological
48. Phosphate			
77. Platinum			
29. Potassium			
84. Praseodymium			
Rhenium			
75. Rhodium			
30. Rubidium			
73. Ruthenium			
84. Samarium			
60. Scandium			
54. Selenium	1.8×10^1	9.0×10^{-2a}	N
43. Silicon			
79. Silver			
28. Sodium			
35. Strontium			
Sulfur			
53. Carbon Disulfide	2.6×10^3	4.0×10^{-2a}	N
53. Carbonyl Sulfide	2.3×10^5	5.3×10^{-1g}	N
53. Hydrogen Sulfide	9.6×10^5	6.4×10^{1a}	
53. Sulfate			
53. Sulfide			
53. Elemental Sulfur			
53. Sulfur Dioxide	6.9×10^4	5.3	N
67. Tantalum			
55. Tellurium			
Terbium			
41. Thallium			
85. Thorium			
Thulium			
45. Tin			
62. Titanium	7.7×10^2	1.3×10^{-1a}	N
70. Tungsten			
85. Uranium			
65. Vanadium			
Ytterbium			
61. Yttrium			
81. Zinc			
63. Zirconium			
TOTAL INORGANICS AND IDENTIFIED ORGANICS	3.8×10^8	7.1×10^3	2.7×10^3

N: DMEG value was not available.

The DMEG value for this compound is based on:

[a] TLV

[b] TLM, lowest

[c] most stringent criteria

[d] carcinogenicity (ordering #)

[e] LC_{50}

[f] NIOSH recommendation

[g] LD_{50}

[h] regulations for protection against radiation

[i] lowest concentration reported to produce effects in vegetation.

All elements not reported: <0.53 $\mu g/m^3$ @ 25°C

TABLE 5-6. SUMMARY OF CHEMICAL TEST RESULTS FOR POKEHOLE GAS

Discharge Severity Range	Compounds Found from Chemical Analysis	
	Health	Ecological
10^3-10^4	CO	CO
10^2-10^3	-	NH_3
10-10^2	As, CO_2, H_2S	-
1-10	CH_4, NH_3, HCN, Li, Ni, SO_2	HCN

TABLE 5-7. SUMMARY OF TEST RESULTS AND DISCHARGE SEVERITY VALUES FOR COAL HOPPER GAS

MEG Category		Estimated Concentration (μg/m³ @ 25°C)	Discharge Severity (Estimated Conc/DMEG Conc) Health	Ecological
1.	Methane	1.4×10^6	4.3[a]	N
	Carbon:			
42.	Carbon Dioxide	8.5×10^7	9.43[a]	N
42.	Carbon Monoxide	2.7×10^8	6.7×10^3[f]	2.2×10^3
72.	Iron Carbonyl	1.3×10^5	1.8×10^2	N
	Sulfur:			
53.	Carbonyl Sulfide	1.5×10^5	3.5×10^{-1}[g]	N
53.	Carbon Disulfide	1.6×10^3	2.7×10^{-2}[a]	N
53.	Hydrogen Sulfide	4.1×10^5	2.7×10^1[a]	N
53.	Sulfur Dioxide	1.3×10^4	9.9×10^{-1}	N
TOTAL INORGANICS AND IDENTIFIED ORGANICS:		3.6×10^8	6.9×10^3	2.2×10^3

N: DMEG value was not available.

The DMEG value for this compound is based on:

[a] TLV

[b] TLM, lowest

[c] most stringent criteria

[d] carcinogenicity (ordering #)

[e] LC_{50}

[f] NIOSH recommendation

[g] LD_{50}

[h] regulations for protection against radiation

[i] lowest concentration reported to produce effects in vegetation.

TABLE 5-8. SUMMARY OF CHEMICAL TEST RESULTS FOR COAL HOPPER GAS

Discharge Severity Range	Compounds Found from Chemical Analysis	
	Health	Ecological
10^3-10^4	CO	CO
10^2-10^3	$Fe(CO)_5$	-
10-10^2	H_2S	-
1-10	CH_4, CO_2	-

The organic and inorganic test results, and the SAM/1A evaluation of those results are presented in Table 5-9. As shown for the inorganics and identified organics, the health and ecological based TDS's are 15 and 90, respectively. The major contributors are trace elements. Ba, Cr, Fe, La, and Li are the major contributors to the health based TDS. The major contributors to the ecological based TDS are Fe and Ti.

For unidentified organic extractables, the worst case health and ecological TDS's are 12,000 and 470, respectively. Table 5-10 lists the worst case compounds used and their respective MEG categories. Table 5-10 also summarizes the major contributors to the TDS and the bioassay test results. The health based bioassay tests indicate a low potential for hazard. Ecological based bioassay tests were not performed on the ash sluice water.

5.2.4 Solid Waste Streams

Two solid waste streams were sampled at the Glen-Gery facility: gasifier ash and cyclone dust. In addition, leaching tests were performed on both solid samples. The solid samples and their leachates were analyzed for organic extractables and trace elements as well as biological activity. The leachates were also analyzed for water quality parameters. The results of these analyses and the SAM/1A evaluation of the results are presented in the following sections.

Gasifier Ash -

Gravimetric and TCO measurements of the extractables from the gasifier ash indicate a total extractables concentration of 116 μg/g. GC/MS analysis identified 77 μg/g as elemental sulfur and 0.71 μg/g as phthalate esters. The remaining 38 μg/g were not identified.

The results of the SAM/1A evaluation of the inorganic and organic test results are summarized in Table 5-11. As indicated in this table, the health based TDS for the inorganics and identified extractables is 1700, while the ecological based TDS

TABLE 5-9. SUMMARY OF TEST RESULTS AND DISCHARGE SEVERITY VALUES FOR ASH SLUICE WATER

MEG Category		Estimated Concentration (μg/ℓ)	Discharge Severity (Estimated Conc/DMEG Conc)	
			Health	Ecology
1A.	Octane	(46,500)		(4.7)
1B.	Dicyclopentadiene	(46,500)		(4.7×10^{2})
2A.	Methyl Iodide	(46,500)	(3.6)	
3A.	Isopropyl Ether	(46,500)		(4.7)
5A.	Benzyl Alcohol, Isobutyl Alcohol, Primary Pentanols	(46,500)		(4.7)[b]
6A.	Ethylene Glycol	(46,500)		(4.7)[b]
7B.	Camphor	(46,500)		(4.2)
8A.	Saturated Long Chain Acids		(2.9)	
	Acetic Acid	(46,500)		(4.6×10^{1})[b]
8B.	β-Propiolactone	(46,500)	(9.7)	(4.6)
8C.	6-Hexanelactam	(46,500)	(3.1)	
8D.	Butyl and Amyl Acetate	(46,500)		(4.6×10^{1})
8D.	Phthalate Esters	40	5.3×10^{-4}[a]	2.7×10^{1}[c]
9A.	Tetramethyl-succinonitrile	(46,500)	(1.0)	
	Acrylonitrile	(46.500)		(4.6×10^{1})[b]
9B.	Benzonitrile, Naphthonitrile	(46,500)		(6.0)
10A.	1, 2 Diaminoethane, 1-Aminopropane	(46,500)		(4.6×10^{1})
10B.	Morpholine	(46,500)		(4.6)
10C.	Aminotoluene, Benzidine, 1-Aminonaphthalene, 2-Aminonaphthalene	(46,500)	(2.8×10^{1})	(4.7×10^{2})[b]
11A.	p-Dimethylamino-azobenzene	(46,500)	(1.6)[d]	
11B.	N, N´-Dimethyl-hydrazine	(46,500)	(9.3×10^{1})[a]	
12A.	N-Nitrosodiethyl-amine	(46,500)	(2.6×10^{1})[d]	
12B.	N Methyl-N-Nitrosoaniline	(46,500)	(2.4)	
13A.	Benzenethiol	(46,500)	(6.2)	
14B.	Dimethyl Sulfoxide	(46,500)	(3.9)	
15A.	Biphenyl	(46,500)	(3.1)[a]	
	Benzene, Toluene, Ethylbenzene, Styrene, Propylbenzene ...	(46,500)		(4.6×10^{1})[b]
15B.	4, 4´ Diphenyl Biphenyl	(46,500)	(1.6)	
	Xylenes, Dialkyl Benzenes, Tetra-hydronaphthalene	(46,500)		(4.6×10^{1})[b]
16A.	Dibromobenzene	(46,500)		(4.7×10^{2})
17A.	4-Nitrobiphenyl	(46,500)	(2.3)[d]	
	Nitrotoluene	(46,500)	--	(4.7)[b]
18A.	Cresols, Alkyl Phenols	(46,500)	(9.3×10^{3})[c]	(9.3×10^{1})[c]
18B.	Hydroxybenzenes	(46,500)	(9.3×10^{3})	(9.3×10^{1})
18C.	Naphthol	(46,500)	(9.3×10^{3})	(9.3×10^{1})
20A.	Nitrophenols	(46,500)	(9.3×10^{3})[c]	
	Dinitrophenols	(46,500)		(4.7×10^{2})[c]
21B.	7, 12-Dimethyl-benz(a)anthracene	(46,500)	(1.2×10^{4})[d]	
21C.	Benzo(e)pyrene	(46,500)	(1.0)[d]	
21D.	Dibenz(a,i)pyrene	(46,500)	(7.2×10^{1})[d]	
22D.	Indeno(1,2,3-cd) pyrene	(46,500)	(1.9)[d]	
23A.	Pyridine, Alkyl Pyridines	(46,500)		(4.7)[b]
23B.	Dihydroacridine	(46,500)	(1.9×10^{1})	
	Acridine	(46,500)		(9.3×10^{1})
23C.	Dibenzo(c,g)carbazole	(46,500)	(3.1×10^{1})[d]	
38.	Aluminum	500	6.2×10^{-3}[a]	5.0×10^{-1}[c]
47.	Ammonia			
47.	Ammonium	3,000	N	N
50.	Antimony	4	5.3×10^{-4}[a]	2.0×10^{-2}[c]
49.	Arsenic	40	1.6×10^{-1}[c]	8.0×10^{-1}[c]
36.	Barium	10,000	2.0[c]	4.0[c]

TABLE 5-9. CONTINUED

MEG Category	Estimated Concentration (μg/ℓ)	Discharge Severity (Estimated Conc/DMEG Conc) Health	Discharge Severity (Estimated Conc/DMEG Conc) Ecology
32. Beryllium	1	3.3×10^{-2a}	1.8×10^{-2c}
51. Bismuth			
37. Boron	1	2.1×10^{-5a}	4.0×10^{-6c}
58. Bromide	10	N	N
82. Cadmium	3	6.0×10^{-2c}	3.0^{c}
34. Calcium	10,000	4.2×10^{-2}	6.25×10^{-1}
Carbon			
42. Carbon Dioxide			
42. Carbon Monoxide			
84. Cerium	100	1.8×10^{-4}	N
31. Cesium	3	2.5×10^{-6}	N
57. Chloride	17,000	1.3×10^{-2}	N
68. Chromium	500	2.0^{c}	2.0^{c}
74. Cobalt	40	5.3×10^{-2a}	1.6×10^{-1c}
78. Copper	100	2.0×10^{-2c}	2.0^{c}
84. Dysprosium	3	1.3×10^{-5}	N
Erbium	1	N	N
Europium	1	N	N
56. Fluoride	600	1.6×10^{-2}	N
Gadolinium	2	N	N
39. Gallium	40	5.4×10^{-4g}	N
44. Germanium	1	1.2×10^{-4a}	N
80. Gold			
64. Hafnium			
Holmium	2	N	N
59. Iodide	1	N	N
Iridium			
72. Iron	5,000	3.33	2.0×10^{1}
72. Iron Carbonyl			
84. Lanthanum	50	5.0	2.0×10^{-1}
46. Lead	20	8.0×10^{-2c}	4.0×10^{-1c}
27. Lithium	400	1.2^{a}	1.1^{c}
Lutetium	1	N	N
33. Magnesium	5,000	5.6×10^{-2a}	5.8×10^{-2e}
71. Manganese	10	4.0×10^{-2c}	1.0×10^{-1c}
83. Mercury			
69. Molybdenum	400	5.3×10^{-3a}	5.7×10^{-2e}
84. Neodymium	10	N	N
76. Nickel	30	1.3×10^{-1f}	3.0^{c}
76. Nickel Carbonyl			
66. Niobium	30	9.1×10^{-5}	N
Nitrogen			
47. Hydrogen Cyanide	60	1.2×10^{-1c}	2.4^{c}
47. Nitrate	17,000	N	N
47. Nitrite			
53. Thiocyanate	2,000	N	N
Osmium			
Palladium			
48. Phosphorus			
48. Phosphate	1,700	N	N
77. Platinum			
29. Potassium	6,000	N	N
84. Praseodymium	10	1.3×10^{-5}	N
Rhenium			
75. Rhodium			
30. Rubidium	200	1.1×10^{-4}	N
73. Ruthenium			
84. Samarium	10	1.3×10^{-5}	N

TABLE 5-9. CONTINUED

MEG Category	Estimated Concentration (μg/ℓ)	Discharge Severity (Estimated Conc/DMEG Conc) Health	Discharge Severity (Estimated Conc/DMEG Conc) Ecology
60. Scandium	7	8.8×10^{-6g}	N
54. Selenium	20	4.0×10^{-1c}	8.0×10^{-1c}
43. Silicon	10,000	6.7×10^{-2}	N
79. Silver	2	8.0×10^{-1c}	4.0×10^{-1c}
28. Sodium	1,000	1.2×10^{-3}	N
35. Strontium	3,000	6.5×10^{-2g}	N
Sulfur			
53. Carbon Disulfide			
53. Carbonyl Sulfide			
53. Hydrogen Sulfide			
53. Sulfate	95,000	N	N
53. Sulfide	3,000	N	N
53. Elemental Sulfur	3,000	N	N
67. Tantalum			
55. Tellurium			
Terbium	1	N	N
41. Thallium			
85. Thorium	40	6.4×10^{-3}	N
Thulium	1	N	N
45. Tin	4	N	N
62. Titanium	10,000	1.1×10^{-1a}	1.2×10^{1e}
70. Tungsten	10	6.7×10^{-4a}	N
85. Uranium	10	1.7×10^{-4h}	2.0×10^{-2c}
65. Vanadium	500	2.0×10^{-1a}	3.3^{e}
Ytterbium	2	N	N
61. Yttrium	40	2.7×10^{-3}	N
81. Zinc	70	2.8×10^{-3c}	7.0×10^{-1c}
63. Zirconium	200	2.7×10^{-3}	N
TOTAL INORGANICS AND IDENTIFIED ORGANICS	2.1×10^{5}	1.5×10^{1}	8.7×10^{1}
UNIDENTIFIED ORGANICS (WORST CASE)	(4.6×10^{4})	(1.2×10^{4})	(4.7×10^{2})

( ) indicate that the worst case analysis, described in Section 5.1.1, for unidentified organics was used.

N: DMEG value was not available.

The DMEG value for this compound is based on:

[a] TLV

[b] TLM, lowest

[c] most stringent criteria

[d] carcinogenicity (ordering #)

[e] LC_{50}

[f] NIOSH recommendation

[g] LD_{50}

[h] regulations for protection against radiation

[i] lowest concentration reported to produce effects in vegetation.

All elements not reported: <0.001 μg/ml.

TABLE 5-10. SUMMARY OF CHEMICAL AND BIOASSAY TEST RESULTS FOR ASH SLUICE WATER

Discharge Severity Range	Compounds Found From Chemical Analysis		Bioassay Test Results	
	Health	Ecological		
10^4-10^5	Fused Polycyclic Hydrocarbons[a]	-	**Health**	
			Ames	Negative
10^3-10^4	-	-	WI-38 (EC_{50})	>600 μℓ/ml of culture
10^2-10^3	-	Alkenes, Cyclic Alkenes, Dienes, Nitrophenols[a]	Rodent Acute Toxicity (LD_{50})	>10 g/kg rat
10-10^2	-	Fe, Ti	**Ecological**	
1-10	Ba, Cr, Fe, La, Li	Phthalate Esters, Ba, Cd, Cr, Cu, HCN, Li, Ni, V	Soil Microcosm	NA

NA - test was not applied.

[a] These categories of organic compounds are the worst case compounds which provide the largest discharge severity for the 46,500 μg/ℓ of identified organics extractables. The worst case compounds corresponding to the categories are listed below.

Category	Compound
Fused Polycyclic Hydrocarbons	7, 12 Dimethylbenz(a)anthracene
Alkenes, Cyclic Alkenes, Dienes	Dicyclopentadiene
Nitrophenols	Dinitrophenols

TABLE 5-11. SUMMARY OF TEST RESULTS AND DISCHARGE SEVERITY VALUES FOP DRY ASH

MEG Category	Estimated Concentration (μg/g)	Discharge Severity (Estimated Conc/DMEG Conc)	
		Health	Ecological
1B. Dicyclopentadiene	(38)		(1.9)
8D. Phthalate Esters	0.71	4.7×10^{-3a}	2.4^{c}
10C. 1-Aminonaphthalene, 2-Aminonaphthalene	(38)		$(1.9)^{b}$
16A. Dibromobenzene	(38)		(1.9)
18A. Cresols, Alkyl Phenols	(38)	$(3.8 \times 10^{1})^{c}$	
18B. Hydroxybenzenes	(38)	$(3.8 \times 10^{1})^{c}$	
18C. Naphthol	(38)	(3.8×10^{1})	
20A. Nitrophenols Dinitrophenols	(38) (38)	$(3.8 \times 10^{1})^{c}$	 $(1.9)^{c}$
21B. 7, 12-Dimethylbenz(a)anthracene	(38)	$(4.9 \times 10^{1})^{d}$	
38. Aluminum	1,000	6.2^{a}	5.0^{c}
47. Ammonia			
47. Ammonium			
50. Antimony	0.5	3.3×10^{-2a}	1.2×10^{-2c}
49. Arsenic	3	6.0^{c}	3.0×10^{-1c}
36. Barium	1,000	1.0×10^{2c}	2.0^{c}
32. Beryllium	1	1.7×10^{1a}	9.1×10^{-2c}
51. Bismuth	18	1.5^{a}	N
37. Boron	13	1.4×10^{-1a}	2.6×10^{-3c}
58. Bromide	6	N	N
82. Cadmium	0.4	4.0^{d}	2.0^{c}
34. Calcium	1,000	2.1	3.1×10^{-1}
Carbon			
42. Carbon Dioxide			
42. Carbon Monoxide			
84. Cerium	180	1.6×10^{-1}	N
31. Cesium	10	4.0×10^{-3}	N
57. Chloride	100	3.8×10^{-2}	N
68. Chromium	190	3.8×10^{2c}	3.8^{c}
74. Cobalt	23	1.5×10^{1a}	4.6×10^{-1c}
78. Copper	200	2.0×10^{1c}	2.0×10^{1c}
84. Dysprosium	3	6.5×10^{-3}	N
Erbium	1	N	N
Europium	1	N	N
56. Fluoride	~59	7.9×10^{-1}	N
Gadolinium	2	N	N
39. Gallium	22	1.5×10^{-1d}	N
44. Germanium	1	5.9×10^{-2}	N
80. Gold			
64. Hafnium	2	1.3	N
Holmium	2	N	N
59. Iodide	0.3	N	N
Iridium			
72. Iron	1,000	3.3×10^{2}	2.0×10^{1}
72. Iron Carbonyl			
84. Lanthanum	160	4.7×10^{-2}	N
46. Lead	12	2.4×10^{1c}	1.2^{c}
27. Lithium	240	3.4×10^{2a}	3.2^{c}
Lutetium	0.3	N	N
33. Magnesium	1,000	5.6^{a}	5.9×10^{-2e}
71. Manganese	69	1.4×10^{2c}	3.4^{c}
83. Mercury	0.28	1.4×10^{-3c}	5.6×10^{-3c}
69. Molybdenum	15	1.0×10^{-1a}	1.1×10^{-2e}
84. Neodymium	34	N	N
76. Nickel	62	1.4×10^{2a}	3.1×10^{1c}
76. Nickel Carbonyl			
66. Niobium	35	5.4×10^{-2}	N
Nitrogen			
47. Hydrogen Cyanide			
53. Thiocyanate			
47. Nitrate			
Nitrite			
Osmium			
Palladium			

TABLE 5-11, CONTINUED

MEG Category	Estimated Concentration (μg/g)	Discharge Severity (Estimated Conc/DMEG Conc) Health	Discharge Severity (Estimated Conc/DMEG Conc) Ecological
48. Phosphorus			
48. Phosphate	1,000	N	N
77. Platinum			
29. Potassium	1,000	N	N
84. Praseodymium	16	1.1×10^{-2}	N
Rhenium	0.1	N	N
75. Rhodium			
30. Rubidium	150	4.2×10^{-2}	N
73. Ruthenium			
84. Samarium	11	6.9×10^{-1}	N
60. Scandium	9	5.6×10^{-3g}	N
54. Selenium	2	2.0×10^{1c}	4.0×10^{-1c}
43. Silicon	1,000	3.3	N
79. Silver	1	2.0^{c}	1.0×10^{-1c}
28. Sodium	1,000	6.2×10^{-1}	N
35. Strontium	490	5.3^{g}	N
Sulfur			
53. Carbon Disulfide			
53. Carbonyl Sulfide			
53. Hydrogen Sulfide			
53. Sulfate			
53. Sulfide			
53. Elemental Sulfur	77	N	N
53. Sulfur Dioxide			
67. Tantalum			
55. Tellurium	0.2	6.7×10^{-2a}	N
Terbium	0.6	N	N
41. Thallium	0.3	1.0×10^{-1a}	N
85. Thorium	29	2.2×10^{1}	N
Thulium	0.2	N	N
45. Tin	2	N	N
62. Titanium	1,000	5.6^{a}	6.2^{e}
70. Tungsten	2	6.7×10^{-2a}	N
85. Uranium	32	2.7×10^{-1h}	3.2×10^{-1c}
65. Vanadium	200	4.0×10^{1a}	6.7^{e}
Ytterbium	2	N	N
61. Yttrium	56	1.9	N
81. Zinc	18	3.6×10^{-1c}	9.0×10^{-1c}
63. Zirconium	350	2.3×10^{1}	N
TOTAL INORGANICS AND IDENTIFIED ORGANICS	13,000	1.7×10^{3}	1.1×10^{2}
UNIDENTIFIED ORGANICS (WORST CASE)	(38)	(4.9×10^{1})	(1.9)

( ) indicate that the worst case analysis, described in Section 5.1.1, for unidentified organics was used.

N: DMEG value was not available.

The DMEG value for this compound is based on:

[a] TLV

[b] TLM, lowest

[c] most stringent criteria

[d] carcinogenicity (ordering #)

[e] LC_{50}

[f] NIOSH recommendation

[g] LD_{50}

[h] regulations for protection against radiation

[i] lowest concentration reported to produce effects in vegetation.

All elements not reported: <0.1 μg/g.

is approximately 100. The major contributors to both TDS's are trace elements. For the health based TDS, they are Ba, Cr, Fe, Li, Mn, and Ni. For the ecological based TDS, they are Cu, Fe, and Ni.

The worst case health and ecological based DS's for the unidentified extractables are nominally 50 and 2, respectively. The specific compounds (and their MEG categories) used in the worst case analysis are indicated in Table 5-12.

Tables 5-12 summarizes the major contributors to the TDS. Also summarized in this table are the results of the bioassay screening tests for the gasifier ash. The health based bioassay tests (Ames, RAM and Rodent Acute Toxicity) indicate a low hazard potential. The only ecological bioassay test conducted on the gasifier ash was the soil microcosm test. While the results from this test cannot be interpreted in terms of low, medium or high hazard potential, the test did indicate that the gasifier ash was clearly more toxic than the cyclone dust.

Ash Leachate -

TCO and gravimetric measurements of the ash leachate indicate a total extractables content of 36,200 μg/ℓ. GC/MS analysis identified 100 μg/ℓ to be phthalate esters. The remaining 36,100 μg/ℓ were unidentified.

The results of the SAM/1A evaluation of the organic and inorganic test results are summarized in Table 5-13. As shown in this table, the health based TDS for inorganics and identified organics is much less than one. The ecological based TDS is approximately 100, with phthalate esters and zinc as the major contributors.

The worst case health and ecological based TDS values for the unidentified organics are 9,300 and 360, respectively. The specific compounds (and their MEG categories) used in the worst case analysis are listed in Table 5-14.

Table 5-14 summarizes the major contributors to the TDS. Also, the results of the ash leachate bioassay tests are summarized. The health based bioassay tests indicate a low potential for hazard. Ecological tests were not performed on the ash leachate.

TABLE 5-12. SUMMARY OF CHEMICAL AND BIOASSAY TEST RESULTS FOR DRY ASH

Discharge Severity Range	Compounds Found from Chemical Analysis	
	Health	Ecological
10^3-10^4	-	-
10^2-10^3	Ba, Cr, Fe, Li, Mn, Ni	-
10-10^2	Fused Polycyclic Hydrocarbons[a], Be, Co, Cu, Pb, Se, Th, V, Zr	Cu, Fe, Ni
1-10	Al, As, Bi, Cd, Ca, Hf, Mg, Si, Ag, Sr, Ti, Y	Alkenes, Cyclic Alkenes and Dienes, Aromatic Amines and Diamines, Ring Substituted Aromatics, Nitrophenols[a], Phthalate esters, Al, Ba, Cd, Cr, Pb, Li, Mn, Ti, V

Bioassay Test Results	
Health	
Ames	Negative
RAM (EC_{50})	>1000 μℓ/ml of culture
Rodent Acute Toxicity (LD_{50})	>10 g/kg rat
Ecological	
Soil Microcosm	*

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*The soil microcosm test results cannot be interpreted in terms of a high, medium, or low potential for hazard but the gasifier ash was clearly more toxic than the cyclone dust.

[a] These categories of organic compounds are the worst case compounds which provide the largest discharge severity for the 38 μg/g of unidentified organics in the ash.

The worst case compounds corresponding to the categories are listed below:

Category	Compound
Fused Polycyclic Hydrocarbons	7, 12-Dimethylbenz(a)anthracene
Alkenes, Cyclic Alkenes and Dienes	Dicyclopentadiene
Aromatic Amines and Diamines	Aminonaphthalenes
Ring Substituted Aromatics	Dibromobenzene

TABLE 5-13. SUMMARY OF TEST RESULTS AND DISCHARGE SEVERITY VALUES FOR ASH LEACHATE

MEG Category		Estimated Concentration (μg/ℓ)	Discharge Severity (Estimated Conc/DMEG Conc)	
			Health	Ecological
1A.	Octane	(36,100)		(3.6)
1B.	Dicyclopentadiene	(36,100)		(3.6×10^2)
2A.	Methyl Iodide	(36,100)	(2.8)	(2.8)
3A.	Isopropyl Ether	(36,100)		(3.6)
5A.	Benzyl Alcohol, Isobutyl Alcohol, Primary Pentanols	(36,100)		$(3.6)^b$
6A.	Ethylene Glycol	(36,100)		$(3.6)^b$
7B.	Camphor	(36,100)		(3.3)
8A.	Saturated Long Chain Acids	(36,100)	(2.3)	
	Acetic Acid			$(3.6 \times 10^1)^b$
8B.	β-Propiolactone	(36,100)	(7.5)	(3.6)
8C.	6-Hexanelactam	(36,100)	(2.4)	
8D.	Butyl and Amyl Acetate	(36,100)		(3.6×10^1)
8D.	Phthalate Esters	94	1.2×10^{-3a}	6.3×10^{1c}
9A.	Acrylonitrile	(36,100)		$(3.6 \times 10^1)^b$
9B.	Benzonitrile, Naphthonitrile	(36,100)		(4.6)
10A.	1, 2 Diaminoethane, 1-Aminopropane	(36,100)		(3.6×10^1)
10B.	Morpholine	(36,100)		(3.6)
10C.	Aminotoluene	(36,100)	(2.1×10^1)	
	Benzidine, 1-Aminonaphthalene, 2-Aminonaphthalene	(36,100)		$(3.6 \times 10^2)^b$
11A.	p-Dimethylazo-aminobenzene	(36,100)	$(1.2)^d$	
11B.	N, N´-Dimethyl-hydrazine	(36,100)	$(7.2 \times 10^1)^a$	
12A.	N-Nitrosodiethyl-amine	(36,100)	$(2.0 \times 10^1)^d$	
12B.	N-Methyl-N-Nitrosoaniline	(36,100)	(1.9)	
13A.	Benzenethiol	(36,100)	(4.8)	
14B.	Dimethyl Sulfoxide	(36,100)	(3.0)	
15A.	Biphenyl	(36,100)	(2.4)	
	Benzene, Toluene, Ethylbenzene, Styrene, Propylbenzene ...	(36,100)		$(3.6 \times 10^1)^b$
15B.	4, 4´ Diphenyl Biphenyl	(36,100)	(1.2)	
	Xylenes, Dialkyl Benzenes, Tetra-hydronaphthalene	(36,100)		$(3.6 \times 10^1)^b$
16A.	Dibromobenzene	(36,100)		(3.6×10^2)
17A.	4-Nitrobiphenyl	(36,100)	$(1.8)^d$	
	Nitrotoluene	(36,100)		$(3.6 \times 10^1)^b$
18A.	Cresols, Alkyl Phenols	(36,100)	$(7.2 \times 10^3)^c$	$(7.2 \times 10^1)^c$
18B.	Hydroxybenzenes	(36,100)	(7.2×10^3)	(7.2×10^1)
18C.	Naphthol	(36,100)	(7.2×10^3)	(7.2×10^1)
20A.	Nitrophenols	(36,100)	$(7.2 \times 10^3)^c$	
	Dinitrophenols	(36,100)		$(3.6 \times 10^2)^c$
21B.	7, 12-Dimethyl-benz(a)anthracene	(36,100)	$(9.3 \times 10^3)^d$	
21D.	Dibenz(a,i)pyrene	(36,100)	$(5.6 \times 10^1)^d$	
23A.	Pyridine, Alkyl Pyridines	(36,100)		$(3.6)^b$
23B.	Dihydroacridine	(36,100)	(1.4×10^1)	
	Acridine	(36,100)		(7.2×10^1)
23C.	Dibenzo(c,g)carbazole	(36,100)	$(2.4 \times 10^1)^d$	

TABLE 5-13. CONTINUED

MEG Category	Estimated Concentration (μg/ℓ)	Discharge Severity (Estimated Conc/DMEG Conc) Health	Discharge Severity (Estimated Conc/DMEG Conc) Ecological
38. Aluminum	6	7.5×10^{-5a}	6.0×10^{-3c}
47. Ammonia			
47. Ammonium			
50. Antimony			
49. Arsenic	4	1.6×10^{-2c}	8.0×10^{-2c}
36. Barium	100	2.0×10^{-2c}	4.0×10^{-2c}
32. Beryllium	1	3.3×10^{-2a}	1.8×10^{-2c}
51. Bismuth			
37. Boron	20	4.3×10^{-4a}	8.0×10^{-4c}
58. Bromide	2	N	N
82. Cadmium	1	2.0×10^{-2c}	1.0^{c}
34. Calcium	4,000	1.7×10^{-4}	2.5×10^{-3}
Carbon			
42. Carbon Dioxide			
42. Carbon Monoxide			
84. Cerium	1	1.8×10^{-6}	N
31. Cesium			
57. Chloride	5,700	4.4×10^{-3}	N
68. Chromium	2	8.0×10^{-3c}	8.0×10^{-3c}
74. Cobalt	1	1.3×10^{-3a}	4.0×10^{-3c}
78. Copper	8	1.6×10^{-3c}	1.6×10^{-1c}
84. Dysprosium			
Erbium			
Europium			
56. Fluoride	60	1.6×10^{-3}	N
Gadolinium			
39. Gallium	1	1.35×10^{-5g}	N
44. Germanium	1	1.19×10^{-4a}	N
80. Gold	1	N	N
64. Hafnium			
Holmium			
59. Iodide	1	N	N
Iridium			
72. Iron	10	6.7×10^{-3}	4.0×10^{-2}
72. Iron Carbonyl			
84. Lanthanum	2	2.0×10^{-1}	8.0×10^{-3}
46. Lead	8	3.2×10^{-2c}	1.6×10^{-1c}
27. Lithium	30	9.1×10^{-2a}	7.9×10^{-2c}
Lutetium			
33. Magnesium	890	9.9×10^{-3a}	1.0×10^{-2e}
71. Manganese	5	2.0×10^{-2c}	5.0×10^{-2c}
83. Mercury			
69. Molybdenum	20	2.7×10^{-4a}	2.9×10^{-3e}
84. Neodymium			
76. Nickel			
76. Nickel Carbonyl			
66. Niobium	1	3.0×10^{-6}	N
Nitrogen			
47. Hydrogen Cyanide			
53. Thiocyanate			
47. Nitrate	50	N	N
47. Nitrite	30	N	N
Osmium			
Palladium			
48. Phosphorus			
48. Phosphate	100	N	N
77. Platinum			
29. Potassium	6,000	N	N
84. Praseodymium			
Rhenium			

TABLE 5-13. CONTINUED

MEG Category	Estimated Concentration (µg/ℓ)	Discharge Severity (Estimated Conc/DMEG Conc) Health	Discharge Severity (Estimated Conc/DMEG Conc) Ecological
75. Rhodium			
30. Rubidium	2	1.1×10^{-6}	N
73. Ruthenium			
84. Samarium			
60. Scandium	1	1.2×10^{-6}[g]	N
54. Selenium	1	2.0×10^{-2}[c]	4.0×10^{-2}[c]
43. Silicon	200	1.3×10^{-3}	–
79. Silver	5	2.0×10^{-2}[c]	1.0[c]
28. Sodium	1,000	1.2×10^{-3}	N
35. Strontium	60	1.3×10^{-3}[g]	N
Sulfur			
53. Carbon Disulfide			
53. Carbonyl Sulfide			
53. Hydrogen Sulfide			
53. Sulfate	2,200	N	N
53. Sulfide			
53. Elemental Sulfur	300	N	N
53. Sulfur Dioxide			
67. Tantalum			
55. Tellurium			
Terbium			
41. Thallium			
85. Thorium			
Thulium			
45. Tin	1	N	N
62. Titanium	10	1.1×10^{-4}[a]	1.2×10^{-2}[e]
70. Tungsten			
85. Uranium	7	1.2×10^{-4}[h]	1.4×10^{-2}[c]
65. Vanadium	1	4.0×10^{-4}[a]	6.7×10^{-3}[e]
Ytterbium			
61. Yttrium	1	6.7×10^{-5}	N
81. Zinc	4,000	1.6×10^{-1}[c]	4.0×10^{1}[c]
63. Zirconium	30	4.0×10^{-4}	N
TOTAL INORGANICS AND IDENTIFIED ORGANICS	19,000	6.8×10^{-1}	1.1×10^{2}
UNIDENTIFIED ORGANICS (WORST CASE)	(36,100)	(9.3×10^{3})	(3.6×10^{2})

( ) indicate that the worst case analysis, described in Section 5.1.1, for unidentified organics was used.

N: DMEG value was not available.

The DMEG value for this compound is based on:

[a] TLV

[b] TLM, lowest

[c] most stringent criteria

[d] carcinogenicity (ordering #)

[e] LC_{50}

[f] NIOSH recommendation

[g] LD_{50}

[h] regulations for protection against radiation

[i] lowest concentration reported to produce effects in vegetation.

All elements not reported: <0.001 µg/ml.

TABLE 5-14. SUMMARY OF CHEMICAL AND BIOASSAY TEST RESULTS FOR ASH LEACHATE

Discharge Severity Range	Compounds Found from Chemical Analysis		Bioassay Test Results	
	Health	Ecological		
10^3-10^4	Fused Polycyclic Hydrocarbons[a]	–	**Health**	
10^2-10^3	–	Alkenes, Cyclic Alkenes, Dienes, Aromatic Amines, Diamines, and Nitrophenols[a]	Ames WI-38 (EC_{50}) Rodent Acute Toxicity (LD_{50})	Negative >600 μℓ/ml of culture >10 g/kg rat
10-10^2	–	Phthalate Esters, Zn	**Ecological** Soil Microcosm	 NA
1-10	–	Cd, Ag		

NA - test was not applied.

[a] These categories of organic compounds are the worst case compounds which provide the largest discharge severity for the 36,100 μg/ℓ of unidentified organics. The worst case compounds corresponding to the categories are listed below:

Category	Compound
Fused Polycyclic Hydrocarbons	7, 12 Dimethylbenz(a)anthracene
Alkenes, Cyclic Amines, and Dienes	Dicyclopentadiene
Aromatic Amines and Diamines	Aminonaphthalenes and Benzidine
Nitrophenols	Dinitrophenols

Cyclone Dust -

Gravimetric and TCO measurements of the cyclone dust indicate a total extractables concentration of 785 μg/g. GC/MS analysis identified 160 μg/g as elemental sulfur, 2 μg/g as phthalate esters, and 1 μg/g as naphthalene, phenanthrene, and fluorene. The remaining 622 μg/g were not identified.

The results of the SAM/1A evaluation of the inorganic and organic test results are summarized in Table 5-15. As shown in this table, the health based TDS for inorganics and identified extractables is 3,000 and the ecological based TDS is approximately 200. As was true for the gasifier ash, the major contributors to the TDS's are trace elements. For the health based TDS, the major trace elements are Mn, Ba, Cr, Fe, Pb, Li, Ni, and Se. For the ecological based TDS, the major contributors are Cd, Fe, Pb, Mn, Ni, and Zn. A large number of other trace elements also had TDS's greater than one.

The worst case health and ecological based TDS's for the unidentified extractables are 800 and 31, respectively. The specific compounds and their MEG categories used in the worst case analysis are shown in Table 5-16.

Table 5-16 summarizes the major contributors to the TDS. In addition, the results of the bioassay tests are presented in this table. The health based bioassay tests indicate a low potential hazard for cyclone dust. The ecological bioassay test results cannot be interpreted as a high, medium or low potential for hazard, however, the test did indicate the cyclone dust was clearly less toxic than the gasifier ash.

Cyclone Dust Leachate -

Inorganic and organic (gravimetric and TCO determination) analyses of the cyclone dust leachate were performed. Water quality analyses and SSMS analysis for trace elements were also conducted.

The test results and the SAM/1A evaluation of the results are listed in Table 5-17. As shown in this table, the health based TDS for inorganics is almost 50, and the ecological based TDS is approximately 200. The major contributor to the health based TDS is Mg, while Mn, Zn, and Pb are the major contributors to the ecological based TDS.

TABLE 5-15. SUMMARY OF TEST RESULTS AND DISCHARGE SEVERITY VALUES FOR CYCLONE DUST

MEG Category		Estimated Concentration (μg/g)	Discharge Severity (Estimated Conc/DMEG Conc) Health	Discharge Severity (Estimated Conc/DMEG Conc) Ecological
1B.	Dicyclopentadiene	(620)		(3.1×10^{1})
8A.	Acetic Acid	(620)		$(3.1)^{b}$
8D.	Butyl and Amyl Acetate	(620)		(3.1)
8D.	Phthalate Ester	2.4	1.6×10^{-2a}	8.0^{c}
10A.	1, 2-Diaminoethane, 1-Aminopropane	(620)		(3.1)
10B.	Ethylmethylamine Diethylamine	(620)		(3.1)
10C.	Aminotoluene 1-Aminonaphthalene 2-Aminonaphthalene	(620) (620)	$(1.9)^{d}$	 $(3.1 \times 10^{1})^{b}$
11B.	Monomethylhydrazine	(620)	$(1.4)^{a}$	
12A.	N, Nitrosodiethylamine	(620)	$(1.7)^{d}$	
15A.	Toluene, Ethylbenzene, Styrene, Propylbenzene, Isopropylbenzene	(620)		$(3.1)^{b}$
15B.	Xylenes, Dialkylbenzene, Tetrahydronaphthalene	(620)		$(3.1)^{b}$
16A.	Dibromobenzene	(620)		(3.1×10^{1})
17A.	Nitrotoluenes	(620)		$(3.1)^{b}$
18A.	Cresols, Alkyl Phenols	(620)	$(6.2 \times 10^{2})^{c}$	$(6.2)^{e}$
18B.	Hydroxybenzenes	(620)	$(6.2 \times 10^{2})^{c}$	$(6.2)^{c}$
18C.	Naphthols	(620)	(6.2×10^{2})	(6.2)
20A.	Nitrophenol	(620)	$(6.2 \times 10^{2})^{c}$	
20A.	2-Amino-4,6-Dinitrophenol	(620)		(3.1×10^{1})
20B.	4,6-Dinitro-O-Cresol	(620)		(6.2)
21A.	Naphthalene	0.4	2.7×10^{-4c}	2.0×10^{-2c}
21A.	Phenanthrene	0.1	2.1×10^{-3d}	N
21B.	7,12-Dimethylbenz(a)anthracene	(620)	$(8.0 \times 10^{2})^{d}$	
21D.	Dibenz(a,i)pyrene	(620)	$(4.8)^{d}$	
22A.	Fluorene	0.1	N	N
23B.	Dihydroacridine, Acridine	(620)	$(1.3)^{g}$	(6.2)
23C.	Dibenzo(c,g)carbazole	(620)	$(2.1)^{d}$	
38.	Aluminum	1,000	6.2^{a}	5.0^{c}
47.	Ammonia			
47.	Ammonium			
50.	Antimony	53	3.5^{a}	1.3^{c}
49.	Arsenic	85	1.7×10^{2c}	8.5^{c}
36.	Barium	1,000	1.0 c 10^{2c}	2.0^{c}
32.	Beryllium	0.8	1.3×10^{1a}	7.3×10^{-2c}
51.	Bismuth	3	2.5×10^{-1g}	N
37.	Boron	5	5.4×10^{-2a}	1.0×10^{-3c}
58.	Bromide	11	N	N
82.	Cadmium	2	2.0×10^{1d}	1.0×10^{1c}
34.	Calcium	1,000	2.1	3.1×10^{-1}
	Carbon			
42.	Carbon Dioxide			
42.	Carbon Monoxide			
84.	Cerium	99	9.0×10^{-2}	N

TABLE 5-15. CONTINUED

MEG Category	Estimated Concentration (μg/g)	Discharge Severity (Estimated Conc/DMEG Conc)	
		Health	Ecological
31. Cesium	15	6.0×10^{-3}	N
57. Chloride	100	3.8×10^{-2}	N
68. Chromium	58	1.2×10^{2c}	1.2^{c}
74. Cobalt	10	6.7^{a}	2.0×10^{-1c}
78. Copper	68	6.8^{c}	6.8^{c}
84. Dysprosium	2	4.3×10^{-3}	N
Erbium	0.9	N	N
Europium	1	N	N
56. Fluoride	240	3.2	N
Gadolinium	1	N	N
39. Gallium	220	1.5^{d}	N
44. Germanium	11	6.5×10^{-1}	N
80. Gold	0.1	N	N
64. Hafnium	3	2.0	N
Holmium	1	N	N
59. Iodide	24	N	N
Iridium			
72. Iron	1,000	3.3×10^{2}	2.0×10^{1}
72. Iron Carbonyl			
84. Lanthanum	130	3.8×10^{-2}	N
46. Lead	230	4.6×10^{2c}	2.3×10^{1c}
27. Lithium	160	2.3×10^{2a}	2.1^{c}
Lutetium	0.3	N	N
33. Magnesium	1,000	5.6^{a}	5.9^{e}
71. Manganese	570	1.1×10^{3c}	2.9×10^{1c}
83. Mercury	280	1.4^{c}	5.6^{c}
69. Molybdenum	57	3.8×10^{-1a}	4.1×10^{-2e}
84. Neodymium	110	N	N
76. Nickel	47	1.0×10^{2a}	2.4×10^{1c}
76. Nickel Carbonyl			
66. Niobium	52	8.0×10^{-2}	N
Nitrogen			
47. Hydrogen Cyanide			
53. Thiocyanate			
47. Nitrate			
47. Nitrite			
Osmium			
Palladium			
48. Phosphorus			
48. Phosphate	1,000	N	N
77. Platinum			
29. Potassium	1,000	N	N
84. Praseodymium	35	2.3×10^{-2}	N
Rhenium	0.1	N	N
75. Rhodium			
30. Rubidium	15	4.2×10^{-3}	N
73. Ruthenium			
84. Samarium	11	6.9×10^{-3}	N
60. Scandium	7	4.4×10^{-3g}	N
54. Selenium	16	1.6×10^{2c}	3.2^{c}

TABLE 5-15. CONTINUED

MEG Category	Estimated Concentration (μg/g)	Discharge Severity (Estimated Conc/DMEG Conc) Health	Discharge Severity (Estimated Conc/DMEG Conc) Ecological
43. Silicon	1,000	3.3	N
79. Silver	5	1.0×10^{1c}	5.0×10^{-1c}
28. Sodium	1,000	6.2×10^{-1}	N
35. Strontium	270	2.9×10^{-2g}	N
Sulfur			
53. Carbon Disulfide			
53. Carbonyl Sulfide			
53. Hydrogen Sulfide			
53. Sulfate			
53. Sulfide			
53. Elemental Sulfur	15,200		
53. Sulfur Dioxide			
67. Tantalum			
55. Tellurium	0.9	3.0×10^{-1a}	N
Terbium	0.6	N	N
41. Thallium	22	7.3^{a}	N
53. Thocyanate			
85. Thorium	97	7.5×10^{1}	N
Thulium	0.2	N	N
45. Tin	39	N	N
62. Titanium	1,000	5.6^{a}	6.2^{a}
70. Tungsten	5	1.7×10^{-1a}	N
85. Uranium	45	3.8×10^{-1h}	4.5×10^{-1c}
65. Vanadium	150	3.0×10^{1a}	5.0^{e}
Ytterbium	2	N	N
61. Yttrium	42	1.4	N
81. Zinc	1,000	2.0×10^{1c}	5.0×10^{1c}
63. Zirconium	110	7.3	N
TOTAL INORGANICS AND IDENTIFIED ORGANICS	3.0×10^{4}	3.0×10^{3}	2.2×10^{2}
UNIDENTIFIED ORGANICS (WORST CASE)	(620)	(8.0×10^{2})	(3.1×10^{1})

( ) indicates that worst case analysis, discussed in Section 5.1.1, for unidentified organics was used.

N: DMEG value was not available.

The DMEG value for this compound is based on:

[a] TLV

[b] TLM, lowest

[c] most stringent criteria

[d] carcinogenicity (ordering #)

[e] LC_{50}

[f] NIOSH recommendation

[g] LD_{50}

[h] regulations for protection against radiation

[i] lowest concentration reported to produce effects in vegetation.

All elements not reported: <0.1 μg/g.

TABLE 5-16. SUMMARY OF CHEMICAL AND BIOASSAY TEST RESULTS FOR CYCLONE DUST

Discharge Severity Range	Compounds Found from Chemical Analysis		Bioassay Tests Results	
	Health	Ecological		
10^{3}-10^{4}	Mn	-	**Health**	
10^{2}-10^{3}	Fused Polycyclic Hydrocarbons[a], As, Ba, Cr, Fe, Pb, Li, Ni, Se	-	Ames	Negative
			RAM(EC_{50})	>1,000 µℓ/ml of culture
			Rodent Acute Toxicity (LD_{50})	>10 g/kg rat
10-10^{2}	Be, Cd, Ag, Th, V, Zn	Alkenes, Cyclic Alkenes, Dienes, Aromatic Amines, Diamines, Ring Substituted Aromatics, Nitrophenols[a], Cd, Fe, Pb, Mn, Ni, Zn	**Ecological**	
			Soil Microcosm	*
1-10	Al, Sb, Ca, Co, Cu, F, Ga, Hf, Mg, Hg, Si, Sr, Tl, Ti, Y, Zr	Phthalate Esters, Al, Sb, As, Ba, Cr, Cu, Li, Mg, Hg, Se, Ti, V		

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* The soil microcosm test results cannot be interpreted in terms of a high, medium or low potential for hazard but the cyclone dust was clearly less toxic than the gasifier ash.

[a] These categories of organic compounds contain the worst case compounds which provide the largest discharge severity for the 622 µg/g of unidentified organics in cyclone dust.

The worst case compounds and their corresponding categories are listed below:

Category	Compound
Fused Polycyclic Hydrocarbons	7, 12-Dimethylbenz(a)anthracene
Alkenes, Cyclic Alkenes, and Dienes	Dicyclopentadiene
Aromatic Amines and Diamines	Aminonaphthalenes
Ring Substituted Aromatics	Dibromobenzene
Nitrophenols	Dinitrophenols

TABLE 5-17. SUMMARY OF TEST RESULTS AND DISCHARGE SEVERITY VALUES FOR CYCLONE DUST LEACHATE

MEG Category		Estimated Concentration (µg/ℓ)	Discharge Severity (Estimated Conc/DMEG Conc)	
			Health	Ecology
1B.	Dicyclopentadiene	(5,400)		(5.0×10^1)
8A.	Saturated Long Chain Acids Acetic Acid	 (5,400)		 $(5.0)^b$
8D.	Butyl and Amyl Acetate	 (5,400)		 (5.0)
9A.	Acrylonitrile	(5,400)		$(5.0)^b$
10A.	1, 2 Diaminoethane, 1-Aminopropane	(5,400)		(5.0)
10C.	Aminotoluene, Benzidine, 1-Aminonaphthalene, 2-Aminonaphthalene	(5,400) (5,400)	(3.0)	 $(5.0 \times 10^1)^b$
11B.	N, N -Dimethyl- hydrazine	(5,400)	$(1.0 \times 10^1)^a$	
12A.	N-Nitrosodiethyl- amine	(5,400)	(3.0)	
15A.	Biphenyl Benzene, Toluene Ethylbenzene, Styrene, Propylbenzene ...	(5,400) (5,400)		 (5.0)
15B.	4, 4´ Diphenyl Biphenyl Xylenes, Dialkyl Benzenes, Tetra hydronaphthalene	 (5,400)		 (5.0)
16A.	Dibromobenzene	(5,400)		(5.0×10^1)
17A.	4-Nitrobiphenyl Nitrotoluene	 (5,400)		 $(5.0)^b$
18A.	Cresols, Alkyl Phenols	(5,400)	$(1.1 \times 10^3)^c$	$(1.0 \times 10^1)^c$
18B.	Hydroxybenzenes	(5,400)	(1.1×10^3)	(1.0×10^1)
18C.	Naphthol	(5,400)	(1.1×10^3)	(1.0×10^1)
20A.	Nitrophenols Dinitrophenols	(5,400) (5,400)	$(1.1 \times 10^3)^c$	 $(5.0 \times 10^1)^c$
21B.	7, 12-Dimethyl- benz(a)anthracene	(5,400)	$(1.4 \times 10^3)^d$	
21D.	Dibenz(a,i)pyrene	(5,400)	(8.0)	
23B.	Dihydroacridine Acridine	(5,400) (5,400)	(2.0)	 (1.0×10^1)
23C.	Dibenzo(c,g)carbazole	(5,400)	$(3.0)^d$	
38.	Aluminum	2,000	2.5×10^{-2a}	2.0^c
47.	Ammonia			
47.	Ammonium			
50.	Antimony	30	4.0×10^{-3a}	1.5×10^{-1c}
49.	Arsenic			
36.	Barium	700	1.4×10^{-1c}	2.8×10^{-1c}
32.	Beryllium	3	1.0×10^{-1a}	5.5×10^{-2c}
51.	Bismuth			
37.	Boron	700	1.5×10^{-2a}	2.8×10^{-2c}
58.	Bromide			
82.	Cadmium	5	1.0×10^{-1c}	5.0^c
34.	Calcium	10,000	4.2×10^{-2}	6.2×10^{-1}
	Carbon			
42.	Carbon Dioxide			
42.	Carbon Monoxide			
84.	Cerium	10	1.8×10^{-5}	N
31.	Cesium	2	1.7×10^{-6}	N
57.	Chloride	10,000	7.7×10^{-3}	N
68.	Chromium	4	1.6×10^{-2c}	1.6×10^{-2c}
74.	Cobalt	300	4.0×10^{-1a}	1.2^c
78.	Copper	90	1.8×10^{-2c}	1.8^c
84.	Dysprosium			
	Erbium			
	Europium			

TABLE 5-17. CONTINUED

MEG Category	Estimated Concentration ($\mu g/\ell$)	Discharge Severity (Estimated Conc/DMEG Conc) Health	Discharge Severity (Estimated Conc/DMEG Conc) Ecological
56. Fluoride	10,000	2.6×10^{-1}	N
Gadolinium			
39. Gallium			
44. Germanium			
80. Gold			
64. Hafnium			
Holmium			
53. Hydrogen Sulfide			
59. Iodide	100	N	N
Iridium			
72. Iron	1,000	6.7×10^{-1}	4.0
72. Iron Carbonyl			
84. Lanthanum	8	8.0×10^{-1}	3.2×10^{-2}
46. Lead	700	2.8^{c}	1.4×10^{1c}
27. Lithium	500	1.5^{a}	1.3^{c}
Lutetium			
33. Magnesium	7,000	7.8×10^{-2a}	8.0×10^{-2e}
71. Manganese	10,000	4.0×10^{1c}	1.0×10^{2c}
83. Mercury	0.5	5.0×10^{-2c}	2.0×10^{-1c}
69. Molybdenum	70	9.3×10^{-4a}	1.0×10^{-2e}
84. Neodymium	5	N	N
76. Nickel			
76. Nickel Carbonyl			
66. Niobium	2	6.1×10^{-6}	N
Nitrogen			
47. Hydrogen Cyanide			
53. Thiocyanate			
47. Nitrate			
47. Nitrite			
Osmium			
Palladium			
48. Phosphorus			
48. Phosphate	300	N	N
77. Platinum			
29. Potassium	10,000	N	N
84. Praseodymium	2	2.6×10^{-1}	N
Rhenium			
75. Rhodium			
30. Rubidium			
73. Ruthenium			
84. Samarium			
60. Scandium	2	2.5×10^{-6e}	N
54. Selenium			
43. Silicon	2,000	1.3×10^{-2}	N
79. Silver	2	8.0×10^{-1c}	4.0×10^{-1c}
28. Sodium	4,000	5.0×10^{-1}	N
35. Strontium			
Sulfur			
53. Carbon Disulfide			
53. Carbonyl Sulfide			
53. Hydrogen Sulfide			
53. Sulfate			
53. Sulfide			
53. Elemental Sulfur	1,000	N	N
53. Sulfur Dioxide			
67. Tantalum			
55. Tellurium			
Terbium			
41. Thallium	1	6.7×10^{-4a}	N
53. Thiocyanate			
85. Thorium			
Thulium			

TABLE 5-17. CONTINUED

MEG Category	Estimated Concentration (μg/ℓ)	Discharge Severity (Estimated Conc/DMEG Conc) Health	Discharge Severity (Estimated Conc/DMEG Conc) Ecological
45. Tin			
62. Titanium	200	2.2×10^{-1}[a]	2.4×10^{-1}[e]
70. Tungsten			
85. Uranium	10	1.7×10^{-4}[h]	2.0×10^{-2}[c]
65. Vanadium	2	8.0×10^{-4}[a]	1.3×10^{-2}[a]
Ytterbium			
61. Yttrium	4	2.7×10^{-5}	N
81. Zinc	10,000	4.0×10^{-1}[c]	1.0×10^{2}[c]
61. Zirconium	4	5.3×10^{-5}	N
TOTAL INORGANICS	89,000	4.7×10^{1}	2.3×10^{2}
UNIDENTIFIED ORGANICS	(5,400)	$(1.4 \times 10\ )$	$(5.0 \times 10\ )$

N: DMEG value was not available.

The DMEG value for this compound is based on:

[a] TLV

[b] TLM, lowest

[c] most stringent criteria

[d] carcinogenicity (ordering #)

[e] LC_{50}

[f] NIOSH recommendation

[g] LD_{50}

[h] regulations for protection against radiation

[i] lowest concentration reported to produce effects in vegetation.

All elements not reported: <0.002 μg/ml.

The worst case health and ecological based TDS's for the unidentified extractables are 1400 and 50, respectively. The specific compounds and their MEG categories used in the worst case analysis are shown in Table 5-18.

Table 5-18 summarizes the major contributors to the TDS. In addition, the bioassay test results of the cyclone leachate are presented in this table. The health based bioassay tests show a low potential for hazard. Ecological based bioassay tests were not performed on the cyclone dust leachate.

5.2.5 Additional Chemical Test Results

This section presents additional analytical results that were not presented in the previous sections. Included are data for both process and waste streams sampled. The major types of data presented in this section are:

- Water Quality Parameters,
- Proximate/Ultimate Analyses,
- Gas Analyses,
- Solid Analyses, and
- Continuous Monitoring.

In addition to the information presented in this section, the Appendix contains complete test data for:

- Trace Element Analyses,*
- Gas Analyses,
- Organic Analyses,
- Bioassay Analyses,
- Gross α and β Analyses, and
- Continuous Monitoring.

TABLE 5-18. SUMMARY OF CHEMICAL AND BIOASSAY TEST RESULTS FOR CYCLONE DUST LEACHATE

Discharge Severity Range	Compounds Found from Chemical Analysis		Bioassay Test Results	
	Health	Ecological		
10^2-10^3	Fused Polycyclic Hydrocarbons[a]	Mn, Zn	Ames	Negative
10-10^2	Mn	Alkines, Cyclic Alkenes, Dienes, Nitrophenols,[a] Pb	WI-38 (EC_{50})	500 µl/ml of culture
1-10	Pb, Li	Al, Cd, Co, Cu, Fe, Li	Rodent Acute Toxicity	NA
			Soil Microcosm	NA

NA - test was not applied

[a] The 5,400 µg/ℓ of unidentified organics was assumed to contain the worst case compounds which provide the largest discharge severity. The worst case compounds and their corresponding categories are listed below:

Category	Compound
Fused Polycyclic Hydrocarbons	7, 12-Dimethylbenz(a)anthracene
Alkenes, Cyclic Alkenes, and Dienes	Dicyclopentadiene
Nitrophenols	Dinitrophenols

Water Quality Parameters -

Table 5-19 summarizes the results of the water quality analyses performed on the ash sluice water, ash leachate and cyclone dust leachate samples. The anion concentrations listed in this table were used in the SAM/1A evaluation discussed earlier. The results of the water quality analyses are also compared to the most stringent state effluent water regulations as of October 1977. These comparisons identified that the following parameters exceeded the most stringent regulations:

- CN^-, PO_4^{-3}, BOD, and TSS in the ash sluice water, and
- F^-, COD, and TSS in the cyclone dust leachate.

Proximate and Ultimate Analyses -

Table 5-20 lists the proximate and ultimate analyses of the coal feedstock, the gasifier ash and the cyclone dust.

Product Gas Analysis -

The concentrations of gaseous components in the product gas were determined by gas chromatography analysis of grab samples, analysis using on-line gas chromatographs and by impinger analysis. The results of these analyses are shown in Table 5-21. The results obtained from analyzing grab and impinger samples compared very well with the ranges of the on-line GC results. These comparisons are shown in Figures 5-2 through 5-9.

Solid Analyses: Particle Morphology, Size Distribution, and Specific Gravity -

Particle morphology, size distribution, and specific gravity analyses were performed on the coal feed, dry ash, cyclone dust and product low-Btu gas particulates. The following text gives a semi-quantitative discussion of the analyses performed on each stream.

TABLE 5-19. SUMMARY OF WATER QUALITY PARAMETERS FOR LIQUID STREAMS FROM THE GLEN-GERY FACILITY

Water Quality Parameter	Ash Sluice Water, μg/ml	Ash Leachate, μg/ml	Cyclone Dust Leachate, μg/ml	Most Stringent State Effluent Regulations as of Oct. 77, μg/ml	States Having Most Stringent Regulations as of Oct. 77[a],[b]
CN^-	0.06			0.02	IL, KY, OH, OK
SCN^-	<2			None	
Cl^-	17	5.7	6.7	250	NM
F^-	0.6		4.4	1	KY, OH, OK
$SO_3^= + SO_4^=$ as $SO_4^=$	95	2.2	63	600	NM
Sulfide	3			None	
NO_3^- as N	17	0.05	0.5	20.0	OK
NO_2^- as N		0.03			
PO_4^{-3} as P	1.7	0.5	<0.05	1.0[c]	OK
NH_4^+ as N	<3			2.5[d] or 4.0[e]	IL, OK
Ca^{+2}		4.0		None	
Mg^{+2}		0.89		None	
Na^+		*		None	
BOD	40 (ppm)			30[e]	CO, IL, NM
TOC	140			None	
COD	20		1800	125	NM
TDS	400		2040	3500	IL
TSS	550		40	15 or 37[f]	CO, IL

[a] Whittaker, Donald E., Pullman-Kellogg, Personal Communication, 21 August 1979.

[b] Based on a survey of 22 states having a potential for furture coal conversion facilities.

[c] Regulation for phosphorus containing compounds.

[d] April to October, regulation for nitrogen containing compounds.

[e] November to March, regulation for nitrogen containing compounds.

[f] Deoxygenating wastes.

TABLE 5-20. PROXIMATE AND ULTIMATE ANALYSIS FOR SOLID SAMPLES FROM THE GLEN-GERY FACILITY

Analysis	Coal Wt. %	Ash Wt. %	Cyclone Dust Wt. %
Proximate:			
Moisture	0.94	0.25	0.71
Ash	11.67	65.81	24.70
Volatile	5.15	1.62	2.88
Fixed Carbon	82.24	32.32	71.71
Sulfur	0.62	-	-
HHV, Btu/lb	12,884	3,193	10,935
Ultimate:			
Moisture	0.94	0.25	0.71
Carbon	81.23	32.98	70.14
Hydrogen	2.14	0.27	1.36
Nitrogen	0.82	0.18	0.62
Chlorine	0.03	0.01	0.01
Sulfur	0.62	0.20	1.52
Ash	11.67	65.81	24.70
Oxygen (by difference)	2.55	0.30	0.95

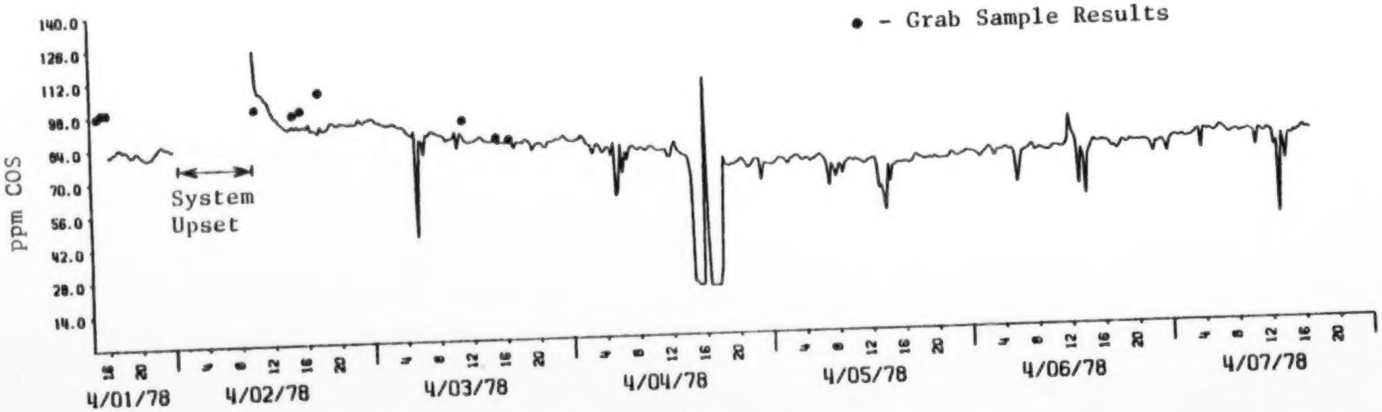
TABLE 5-21. AVERAGE COMPOSITION OF THE PRODUCT LOW-BTU GAS[a]

Component	Volume %	No. of Samples Taken[b]
CO_2	5.5 (5.0-7.5)[c]	24
H_2	16.3	24
O_2	0.9	24
N_2	51.6	24
CH_4	0.2	24
CO	25.5 (25-26)[c]	24
NH_3	180 ppmv (100-200)[c]	6
CN^-	32 ppmv	4
SCN^-	8 ppmv	4
C_1	1910 (1500-4500)[c] ppmv	20
C_2	<1 ppmv	20
C_3	3 ppmv	20
$Fe(CO)_5$	0.004 ppmv	3
$Ni(CO)_4$	0.01 ppmv	3
H_2S	690 (600-700)[c] ppmv	22
COS	93 (70-100)[c] ppmv	26
SO_2	21 (4-30)[c] ppmv	19
CS_2	<1 (<10)[c] ppmv	20
Total Sulfur	730 ppmv	7
Heating Value (dry, @ 70°F)	5.1 MJ/m^3, 137 Btu/SCF	24

[a] Dry basis; average moisture content was 5.9%

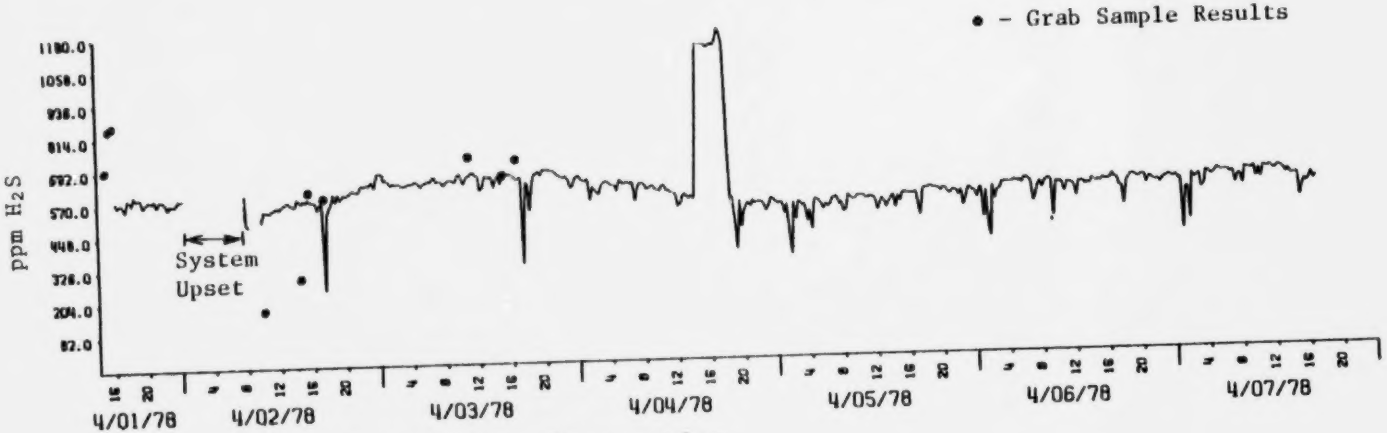
[b] Sampling dates 3/28 to 4/3.

[c] Ranges for on-line gas chromatograph results



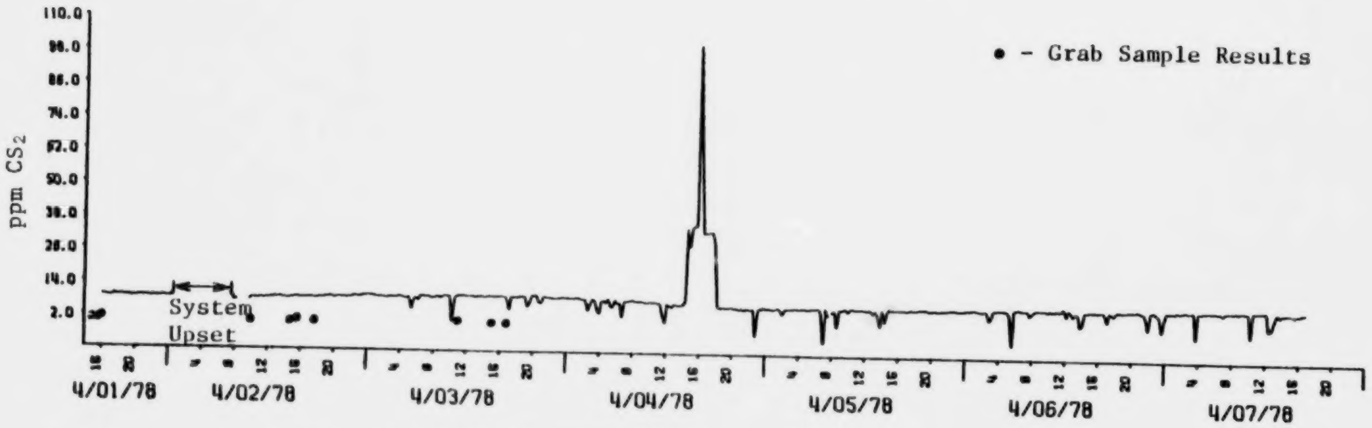
Note: Monitored by Radian Corporation

Figure 5-2. On-Line Gas Chromatograph Results - Carbonyl Sulfide Concentrations in the Product Gas, ppm.



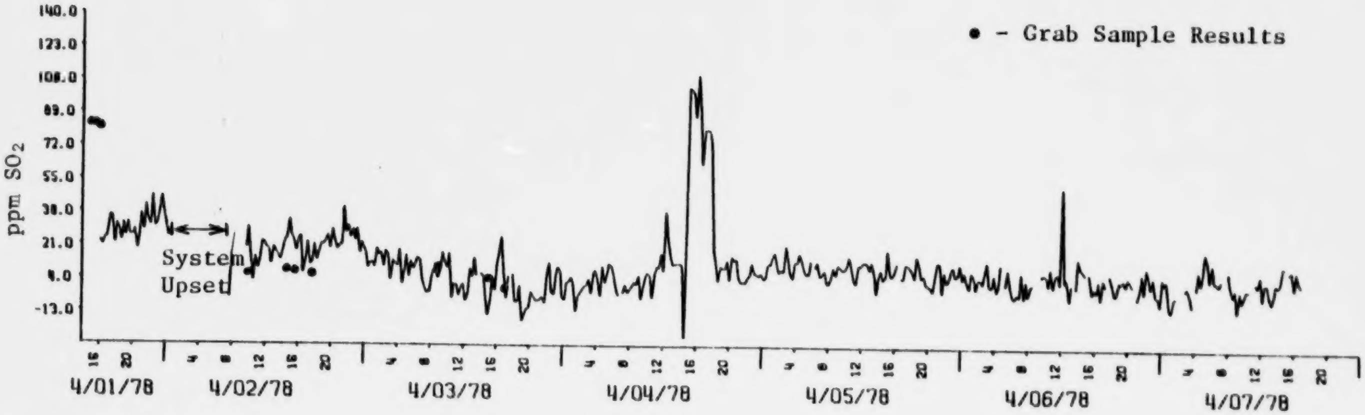
Note: Monitored by Radian Corporation

Figure 5-3. On-Line Gas Chromatograph Results - Hydrogen Sulfide Concentration in the Product Gas, ppm.



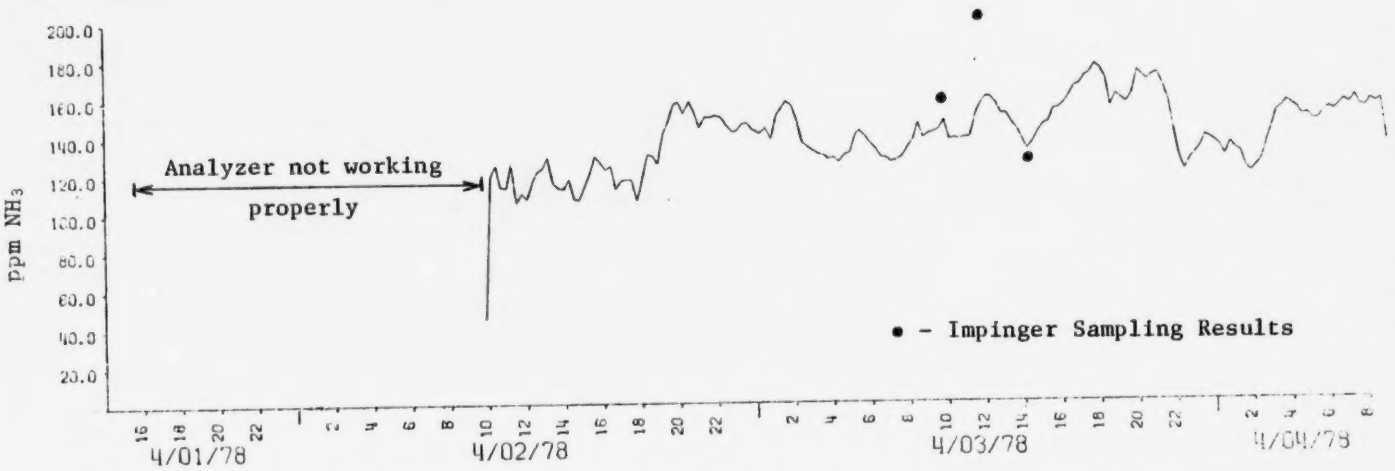
Note: Monitored by Radian Corporation.

Figure 5-4. On-Line Gas Chromatograph Results - Carbon Disulfide Concentration in the ProductGas, ppm.



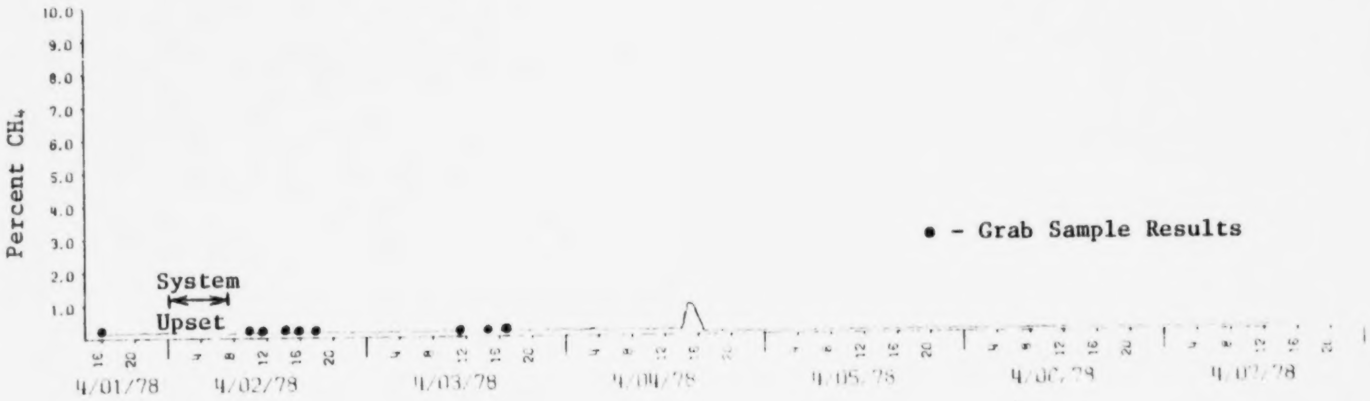
Note: Monitored by Radian Corporation.

Figure 5-5. On-Line Gas Chromatograph Results - Sulfide Dioxide Concentration in the Product Gas, ppm.



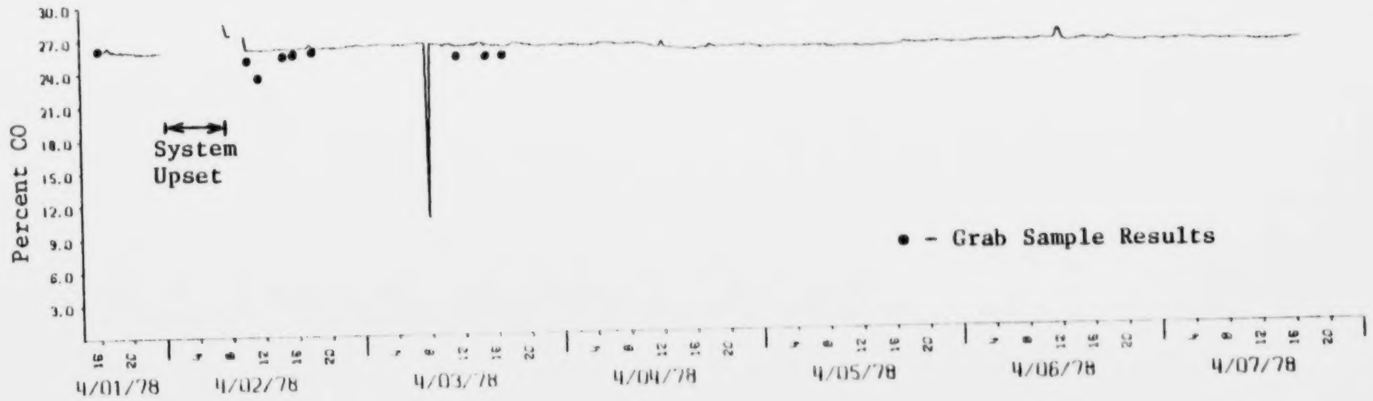
Note: Monitored by Radian Corporation.

Figure 5-6. On-Line Gas Chromatograph Results - Ammonia Concentration in the Product Gas, ppm.



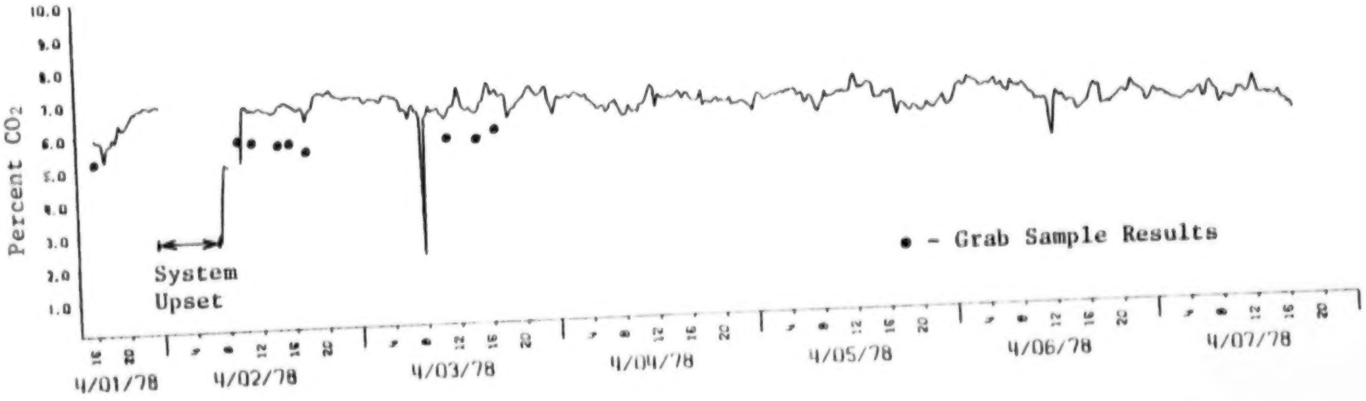
Note: Monitored by Radian Corporation

Figure 5-7. On-Line Gas Chromatograph Results - Percentage of Methane Concentration in the Product Gas.



Note: Monitored by Acurex Corporation

Figure 5-8. On-Line Gas Chromatograph Results - Percentage of Carbon Monoxide Concentration in the Product Gas.



Note: Monitored by Acurex Corporation.

Figure 5-9. On-Line Gas Chromatograph Results - Percentage of Carbon Dioxide Concentration in the Product Gas.

Coal Feed - Most of the coal particles were elongated squares with a few tending to be spherical. They were roughly 25 to 40 mm (1 to 1½ in.) by 25 to 40 mm (1 to 1½ in.) by 15 mm (½ in.). Most of the surfaces were relatively smooth with ends that appeared to have been pulled or snapped apart, as in a crushing procedure. All particles were a uniform black color. The material was homogeneous and appeared to have few holes or pock marks. Particle size distribution was not determined for the coal feed due to the large particle sizes. The specific gravity was approximately 1.60.

Dry Ash - Most of the dry ash particles were elliptical and about 14 mm to 25 mm (½ to 1 in.). However, the exact size varied from greater than 75 mm (3 in.) in length to very small dust particles. The material was easily crushed or broken apart and the surface of all particles was craggy with many pock marks. The particles were multicolored and appeared to be agglomerated. A series of honeycomb holes was clearly evident throughout the larger particles. The particle size distribution was not determined due to the large size of most particles. The specific gravity was 1.64.

Cyclone Dust - The shape of the cyclone dust particles varied from spherical to prismatic. In general, the particles were elongated with relatively smooth surfaces. Few honeycomb holes or pock marks were evident. The material was homogeneous and the particles were pure black. The size distribution of the cyclone dust is shown in Table 5-22. The cyclone dust had a specific gravity of 1.63.

Product Gas Particulates - The product gas particulates, collected with the SASS train, were similar to the cyclone dust. The material was black with relatively smooth walls but the average particulate was smaller and more spherical than the cyclone dust. The size distribution of the product gas particulates was determined using a Brink Model B Cascade Impactor. The results of the impactor sampling are presented in Table 5-23.

Continuous Monitoring -

Eleven components in the product low-Btu gas were continuously monitored. However, five components, ethane, ethylene, propane, propylene, and C_4 and higher hydrocarbons were not detected at a significant concentration. The remaining six compounds monitored were COS, H_2S, CS_2, SO_2, CH_4, and NH_3. Table

TABLE 5-22. SIZE DISTRIBUTION FOR CYCLONE DUST

Size Range (μm)	% in This Range
>1000	1.00
<1000, >710	0.25
<710, >595	0.32
<595, >425	0.91
<425, >250	5.65
<250, >177	8.98
<149, >125	6.87
<125, >74	8.65
>75	26.84
<75	40.77

TABLE 5-23. PARTICULATE SIZE DISTRIBUTION IN THE PRODUCT LOW-BTU GAS

	Particulates Collected (g)	% of Particulates Collected	Estimated Particle Diameter (μm)		
			Aerodynamic Impaction	Aerodynamic	Stokes
Cyclone	349.39	99.70	>6.80		
Stage 1	0.86	0.24	3.95	3.78	3.77
Stage 2	0.04	0.01	2.38	2.22	2.21
Stage 3	0.04	0.01	1.61	1.45	1.44
Stage 4	0.02	0.01	1.02	0.88	0.86
Stage 5	0.03	0.01	0.67	<0.54	<0.52
Stage 6	0.07	0.02	<0.67	0.54	0.52
	350.45	100.00			
Cyclone	76.06	94.38	>15.0		
Stage 1	2.54	3.15	7.91	7.73	7.73
Stage 2	0.27	0.34	4.76	4.59	4.59
Stage 3	0.15	0.19	3.22	3.06	3.05
Stage 4	0.12	0.15	2.05	1.89	1.88
Stage 5	0.06	0.07	1.35	1.19	1.18
Stage 6	1.39	1.72	<1.35		
	80.59	100.00			

5-24 indicates the approximate range of concentrations that were detected for each component. Figures 5-2 through 5-7 illustrate the variability of the continuous monitoring data over the seven day monitoring period. The results of analyzing grab samples of the product low-Btu gas are indicated by the darkened circles on those figures. As shown, the grab sample analyses and the continuous gas chromatograph analyses compared very well.

In addition to Radian's continuous monitoring system, additional continuous monitoring systems were in use as part of the DOE's testing program. Those data are presented in the Appendix. Table A-33 summarizes all of the continuous monitoring test data contained in the Appendix.

5.3 CYCLONE PARTICULATE REMOVAL EFFICIENCY

An attempt was made to determine the cyclone particulate removal efficiency by simultaneously measuring the particulate loadings in the gas entering and exiting the cyclone. The results of these tests are given in Table 5-25.

The sampling locations at the cyclone inlet did not allow collection of a representative particulate sample. There was only one and one-half duct diameters between the gasifier exit and cyclone inlet. Physical constraints allowed traversing in only the horizontal direction. Therefore, the vertical stratification of particulate matter would not be detected and the inlet particulate loadings are likely to be low. In addition, very high results for three of the five outlet particulate loadings indicated possible reentrainment of collected material.

Neglecting these three high loading values, a cyclone particulate collection efficiency of (65 ± 20)% was calculated. This should be considered as only a rough estimate since the inlet particulate loading data are highly unreliable.

5.4 LOW-BTU GAS COMBUSTION TESTS

Samples of the combustion products from burning low-Btu gas were obtained from a small test burner (constructed of bricks) installed at the Glen-Gery facility. The product low-Btu gas flow rate (taken as a slipstream from the main product

TABLE 5-24. SUMMARY OF CONTINUOUS MONITORING TEST DATA FOR PRODUCT LOW-BTU GAS

Compound	Detected Concentration Range
Carbonyl Sulfide	70-100 ppmv
Hydrogen Sulfide	600-700 ppmv
Carbon Disulfide	10 ppmv
Sulfur Dioxide	4-30 ppmv
Methane	0.15-0.45 %
Ammonia	100-200 ppmv

TABLE 5-25. CYCLONE EFFICIENCY TEST RESULTS

		Entrained Particulates, g/m^3		
Run #	Date	Cyclone Inlet	Cyclone Outlet	Removal Efficiency
1	3/29	0.36	1.30*	*
2	3/29	0.22	0.078	64.5%
3	3/29	0.15	0.046	69.3%
4	3/30	0.20	1.81*	*
5	3/30	0.16	1.98*	*

*Indicates a higher outlet particulate loading than inlet loading which may be due to reentrainment of collected particulate matter.

gas line) to the test burner was reported by Acurex to be 64.3 m^3/hr @ 25°C (2270 SCFH). The test burner flue gas flow rate was measured at 295 m^3/hr @ 25°C (10,400 SCFH). The measured flue gas composition for the test burner is presented in Table 5-26.

The flue gas oxygen content of 10.8% indicates that the burner was operating at a very high level of excess air. At 10% excess air, the flue gas oxygen content would be approximately 1%. Rough material balances for oxygen and nitrogen estimate that the test burner had about 400% excess air. This may have, at least partly, been the result of air leaking into the combustion chamber through cracks in the brick walls. The products of combustion most directly effected by operating with excess air are hydrocarbons and NO_x. The effect on both is extremely difficult to predict since very complex relationships between reaction kinetics, combustion temperature, and residence time are involved. In general, increases in excess air result in increased production of NO_x.

Using the flow rates cited above and the gas compositions given in Table 5-21 for the product gas and Table 5-26 for the test burner flue gas, material balances for carbon, hydrogen, nitrogen and oxygen were calculated according to the procedures described in Section 2.3. As mentioned above, the oxygen and nitrogen balances were used to estimate the combustion air flow rate of 250 m^3/hr (N_2 balance) and 275 m^3/hr (O_2 balance). A carbon mass balance resulted in a calculated inlet carbon rate of 10± 1 kg/hr and an outlet carbon mass rate of 14± 2 kg/hr. The failure of the carbon balance to close within the estimated confidence limits of the data and the relatively close agreement between the combustion air flow rates based on oxygen and nitrogen indicate that the flow rate of the low-Btu product gas may be as much as 60% low. However, the hydrogen balance closes within the confidence limits of the data with 8.7± 1.2 kg/hr into the test burner and 10± 1.4 kg/hr exiting in the flue gas, indicating that the flow rates and analyses are accurate within estimated limits.

TABLE 5-26. TEST BURNER FLUE GAS COMPOSITION *

Component	Average Concentration
CO_2 (vol%)	9.5
O_2 (vol%)	10.8
N_2 (vol%)	79.7
C_1 (vppm)	0.4
C_2 (vppm)	ND
C_3 (vppm)	ND
H_2S (vppm)	ND
COS (vppm)	ND
SO_2 (vppm)	491
CS_2 (vppm)	ND
Total S (vppm)	199
NO_x (vppm)	267
CN^- (vppm)	< 3
SCN^- (vppm)	2
NH_3 (vppm)	< 5
$Fe(CO)_5$ (vppb)	17
$Ni(CO)_4$ (vppb)	3
Total Organics ($\mu g/m^3$ @ 25°C)	1910

Flue gas flow rate: 174 scfm (4.87 m^3/min @ 25°C)

ND: Not detected.

*Dry basis: average moisture content was 5.7%

SECTION 6.0

CONCLUSIONS AND RECOMMENDATIONS

Conclusions and recommendations from the source test and evaluation of the Glen-Gery gasification facility are presented in this section.

A summary of the waste stream characterization is presented in Table 6-1. As shown in this table, all seven waste streams have a potential for hazardous effects according to the SAM/1A evaluation. However, the discharge severity (DS) values are low compared to the DS values for waste streams from a bituminous coal gasifier (Ref. 1). In addition, the bioassay tests indicated a low potential for hazardous effects for the solid and liquid Glen-Gery waste streams. And, the hazardous effects of the gaseous waste streams are reduced because of their low flow rates.

Table 6-1 also gives priorities, based on the SAM/1A evaluation, for future chemical analyses for each waste stream. In addition, it is recommended that specific compounds be identified for the waste streams in which the worst case unidentified organics are the major contributors to the total stream discharge severity (TDS). Specific discussions of the conclusions and recommendations for each waste stream are presented in the following text.

Pokehole Gas -

The pokehole gas contains inorganic gases and a few trace elements at potentially hazardous concentrations (greater than their DMEG values). However, the low flow rate of this discharge stream reduces its hazardous effects. In addition, better seals on the pokeholes and better maintenance of the seals may greatly reduce the amount of escaping gas. If further control of this stream is necessary, an inert gas could be injected into the pokehole during the poking operation. Good ventilation of the pokehole area would also help reduce worker exposure.

TABLE 6-1. SUMMARY OF THE CHARACTERIZATION OF WASTE STREAMS FROM THE GLEN-GERY FACILITY.

Waste Stream	Health Based Results	Ecological Based Results	Priority for Quantitative Chemical Analysis High (TDS, 10^2 +)	Medium (TDS, 10-10^2)	Low (TDS, 1-10)	Conclusions	Recommendations
Pokehole Gas:			CO, NH_3	As, CO_2, H_2S	CH_4, NH_3, HCN, Li, Ni, SO_2	• potentially hazardous according to SAM/IA evaluation • low flow	• better seals • better maintenance • ventilation • injection of inert gas during poking operation
Total Stream Discharge Severity[a,b]	7.1×10^3	2.7×10^3					
Bioassay Tests	NC	NC					
Coal Hopper Gas:			CO, $Fe(CO)_5$	H_2S	CH_4, CO_2	• potentially hazardous according to SAM/IA evaluation • low flow	• collect and recycle to inlet air or vent to atmosphere • keep workers out of area
Total Stream Discharge Severity[a]	6.9×10^3	2.2×10^3					
Bioassay Tests	NC	NC					
Ash Sluice Water:			Fused Polycyclic Hydrocarbons, Alkenes, Cyclic Alkenes, Dienes, and Nitrophenols[e]	Fe, Ti	Phthalate Esters, Ba, Cd, Cr, Cu, CN, Fe, La, Li, Ni, V	• potentially hazardous according to SAM/IA evaluation • low potential for hazard according to Bioassay Tests • LD_{50} and EC_{50} were above maximum dosages administered • TDS, BOD, PO_4^{-3}, and CN^- exceed the most stringent water effluent standards	• collect and reuse as ash sluice water
Total Stream Discharge Severity[a]	1.2×10^4	5.6×10^2					
Bioassay Tests	Low[c]	NC					
Ash:			Be, Cr, Fe, Li, Mn, Ni	Fused Polycyclic Hydrocarbons[e], Be, Co, Cu, Fe, Pb, Ni, Se, Th, V, Zr	Alkenes, Cyclic Alkenes and Dienes, Aromatic Amines and Diamines, Ring Substituted Aromatics, Nitrophenols[e], Phthalate Esters, Al, As, Ba, Bi, Cd, Ca, Cr, Hf, Pb, Li, Mg, Mn, Si, Ag, Sr, Ti, V, Y	• potentially hazardous according to SAM/IA evaluation • Bioassay Tests indicate a low potential for hazard • LD_{50} and EC_{50} were above maximum dosages administered	• landfill is a possible disposal technique • further analyses for unidentified organics and bioassay tests for ecological effects
Total Stream Discharge Severity[a]	1.7×10^3	1.1×10^2					
Bioassay	Low[c]	d					

TABLE 6-1. CONTINUED

Waste Stream	Health Based Results	Ecological Based Results	Priority for Quantitative Chemical Analysis High (TDS, 10^3 +)	Medium (TDS, $10-10^3$)	Low (TDS, 1-10)	Conclusions	Recommendations
Ash Leachate:			Fused Polycyclic Hydrocarbons, Alkenes, Cyclic Alkenes, Dienes, Aromatic Amines and Diamines, and Nitrophenols[e]	Phthalate Esters, Zn	Cd, Ag	• potentially hazardous according to SAM/1A evaluations • bioassay tests indicate low potential • LD_{50} and EC_{50} were above maximum dosages administered • RCRA standards are not exceeded for Trace Elements	• further analyses for unidentified organics and bioassay tests for ecological effects
Total Stream Discharge Severity[a]	9.3×10^3	4.7×10^2					
Bioassay Tests	Low[c]	NC					
Cyclone Dust:			Fused Polycyclic Hydrocarbons[e], As, Be, Cr, Fe, Pb, Li, Mn, Ni, Se	Alkenes, Cyclic Alkenes, and Dienes, Aromatic Amines and Diamines, Ring Substituted Aromatics, Nitrophenols[e], Be, Cd, Fe, Pb, Mn, Ni, Ag, Th, V, Zn	Phthalate Esters, Al, Sb, As, Ba, Ca, Cr, Co, Cu, F, Ga, Hf, Li, Mg, Hg, Se, Si, Sr, Tl, Ti, V, Y, Zr	• potentially hazardous according to SAM/1A evaluation • small flow rate • bioassay tests indicate low potential for hazard • LD_{50} and EC_{50} were above maximum dosage administered	• landfill may not be acceptable • incineration
Total Stream Discharge Severity[a]	3.8×10^3	2.5×10^2					
Bioassay Tests	Low[c]	d					
Cyclone Dust Leachate:			Mn, Zn, Fused polycyclic Hydrocarbons[e]	Mn, Pb, Alkenes, Cyclic Alkenes, Dienes, and Nitrophenols[e]	Al, Cd, Co, Cu, Fe, Pb, Li	• potentially hazardous according to SAM/1A evaluation • bioassay tests indicate low potential for hazard • F^- exceeds most stringent water effluent standards • Pb exceeds RCRA standards	• quantitative analysis for Pb to determine if its concentration actually exceeds RCRA guidelines
Total Stream Discharge Severity[a]	1.4×10^3	2.8×10^2					
Bioassay Tests	Low[c]	NC					

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[a] Total stream discharge severity for a stream is the estimated concentrations of components (or classes of compounds) in the stream divided by their respective DMEG values.

[b] The discharge severity values for the pokehole gas were calculated using the product gas analyses.

[c] Health tests include Ames, Cytotoxicity (WI-38, RAM) and Rodent Acute Toxicity.

[d] The soil microcosm test results cannot be interpreted in terms of high, medium or low potential for hazard. However, the gasifier ash was clearly more toxic than the cyclone dust.

[e] These categories of organic compounds contain the worst case compounds which provide the largest potential discharge severity for the unidentified organics of each waste stream. The categories and their corresponding worst case compounds are listed below:

Category	Compound
Fused Polycyclic Hydrocarbons	7, 12-Dimethylbenz(a)anthracene
Alkenes, Cyclic Alkenes and Dienes	Dicyclopentadiene
Aromatic Amines and Diamines	Aminonaphthalenes
Ring Substituted Aromatics	Dibromobenzene
Nitrophenols	Dinitrophenols

NC: test not conducted.

Ash and Ash Leachate -

According to the SAM/1A evaluation for the gasifier ash and ash leachate, trace elements, unidentified organics, and identified organics were found in potentially hazardous concentrations. The major contributors to the ash TDS are trace elements, including Ba, Cr, Fe, Li, Mn, and Ni. The major contributors for the ash leachate are the unidentified organics.

However, bioassay tests on both samples indicate a low potential for hazardous health effects. And, trace element concentrations found in the ash leachate do not exceed the Resource Conservation and Recovery Act (RCRA) standards. In light of the bioassay test results and the fact that RCRA standards are not exceeded, land filling could be an acceptable disposal practice. However, additional test work is recommended in order to define the unidentified organics found in the ash and leachate samples. Also, ecological based bioassay tests should be conducted.

Cyclone Dust and Cyclone Dust Leachate -

Unidentified organics, trace elements and identified organics were found in potentially hazardous concentrations in the cyclone dust. The major contributors according to the SAM/1A evaluation are the worst case categories of unidentified organics, As, Ba, Cr, Fe, Pb, Li, Mn, Ni, and Se. However, bioassay tests indicate a low potential for hazardous health effects. The small flow rate of this stream also reduces its hazardous effects.

Bioassay tests on the cyclone dust leachate indicate a low potential for hazardous health effects. However, unidentified organics (the cyclone dust leachate was not subjected to GC/MS for organics identification) and trace elements were found to be in potentially hazardous concentrations according to the SAM/1A analysis. In addition, the fluoride concentration exceeds the most stringent state water effluent standard, and the Pb concentration determined by SSMS exceeds the RCRA guideline. A more quantitative Pb analysis is recommended to determine if RCRA standards are actually exceeded and, therefore, if the cyclone dust could be landfilled. Due to the high carbon content of the cyclone dust and the high Pb concentration of the leachate, incineration of the cyclone dust is the recommended disposal technique. Combustion gases from the incinerator should be analyzed for volatile elements.

Coal Hopper Gas -

The major potential hazard in the coal hopper gas was found to be CO. However, a number of other inorganic gases as well as CH_4 were measured in potentially hazardous concentrations. As was true for the pokehole gas, the low flow rate of the coal hopper gas greatly reduces its hazardous effects. Collecting and venting the gas to the gasifier inlet air or dispersing the gas in the ambient air are the recommended control techniques. Since the coal hopper rarely requires manual attention, workers could be kept out of the area to prevent exposure to the potentially hazardous gases.

Ash Sluice Water -

Unidentified organics, identified organics, and trace elements were found in potentially hazardous concentrations in the ash sluice water according to the SAM/1A evaluation. The major contributors were unidentified organics for which the worst case compounds were used to compute the DS.

TSS, BOD, PO_4^{-3} and CN^- were found in concentrations that exceed the most stringent state effluent water standards, as shown in Table 5-19. However, bioassay tests indicate a low potential for hazard. Detailed organic analyses are recommended to determine the actual organic compounds present in the ash sluice water. Bioassay tests should also be conducted to determine the potential ecological effects of the ash sluice water.

The potential harmful effects of the ash sluice water could be essentially eliminated by separating it from the ash slurry and reusing it the next time ash is removed. Recycling would, of course, increase the concentration of dissolved components in the sluice water. However, because the dissolved species come from the ash, their concentrations would not increase to the point of solids precipitation. Thus, there would be no need for a blowdown stream. A disadvantage of recycling the sluice water is that the water that remains with the ash will also contain increased concentrations of dissolved components. Whether this poses a greater harmful effect than discharging the "once through" ash sluice water would need to be determined on an individual basis.

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APPENDIX - DATA LISTING

TABLE A-1. TRACE ELEMENT CONCENTRATION IN THE COAL FEEDSTOCK

	Concentration (μg/g)		Concentration (μg/g)		Concentration (μg/g)
Al	≥1000	Ho	0.3	Ru	
Sb	0.8	In	Std	Sm	2
As	5	I	2	Sc	1
Ba	230	Ir		Se	2
Be	0.3	Fe	≥1000	Si	≥1000
Bi	0.3	La	7	Ag	0.3
B	4	Pb	8	Na	≥1000
Br	3	Li	45	Sr	39
Cd	0.3	Lu	0.1	S	≥1000
Ca	≥1000	Mg	≥1000	Ta	
Ce	11	Mn	11	Te	≤0.2
Cs	1	Hg	0.42*	Tb	0.1
Cl	18	Mo	3	Tl	≤0.3
Cr	22	Nd	4	Th	3
Co	3	Ni	5	Tm	<0.1
Cu	25	Nb	5	Sn	1
Dy	0.5	Os		Ti	≥1000
Er	0.2	Pd		W	0.5
Eu	0.2	P	660	U	2
F	≈45	Pt		V	18
Gd	0.3	K	≥1000	Yb	0.6
Ga	8	Pr	2	Y	7
Ge	0.5	Re		Zn	16
Au		Rh		Zr	28
Hf		Rb	8		

Concentrations determined by SSMS except where indicated.
*Determined by atomic absorption spectrophotometry.
Std - used as the standard
All element concentrations not reported <0.1 μg/g

TABLE A-2. TRACE ELEMENT CONCENTRATION IN THE PRODUCT GAS -

	Particulates (µg/g)		Gases		Particulates (µg/g)		Gases
	>3µ	<3µ	(µg/m³ @ 25°C)		>3µ	<3µ	(µg/m³ @ 25°C)
Al	>30	>4000		Mo	90	600	
Sb	200	2000	2	Nd	30	40	
As	≥900	2000	≤50	Ni	Int	200	20
Ba	600	≥9000		Nb	30	50	
Be	0.4	2		Os			
Bi	40	700		Pd			
B	0.6	300		P	>800	3000	10
Br	5	90		Pt			
Cd	20	300	10	K	>300	≥9000	*
Ca	≥900	≥9000	*	Pr	6	40	
Ce	40	300		Re	<0.1		
Cs	4	9		Rh			
Cl	≥900	≥9000	*	Rb	30	70	7
Cr	90	600	6	Ru			
Co	30	60		Sm	9	30	
Cu	200	500	10	Sc	4	40	
Dy	2			Se	30	500	20
Er	<0.9			Si	20	2000	
Eu	1.9	5.0		Ag	40	300	
F	≈200	≈900		Na	>90	≥9000	
Gd	2	9		Sr	200	600	
Ga	≥900	4000	10	S	>200	≥9000	*
Ge	0.9	20		Ta	≤0.9		
Au	<0.2			Te	20	≤30	
Hf	0.9			Tb	0.7	3	
Ho	0.9			Tl	90	≤20	
In	Std	Std		Th	9	≤80	
I	0.9	4		Tm	≤0.1		
Ir				Sn	200	3000	
Fe	≥900	≥9000		Ti	≥900	3000	800
La	50	200		W	9	90	
Pb	≥900	≥9000		U	6	≤90	
Li	70	50	50	V	30	300	0.8
Lu	0.3			Yb	0.9		
Mg	≥900	≥9000		Y	20	90	
Mn	300	400	3	Zn	≥900	≥9000	40
Hg	ND	ND		Zr	40	600	

Concentrations determined by SSMS

Sample was thermally ashed @ 350°C for one hour in a laboratory furnace in a quartz crucible prior to analysis.

Element concentrations not reported: Particulates >3µ,<0.093 µg/g
<2µ,<4.3 µg/g

Gas, <0.53 µg/m³

*Major component: not detectable because >9000 µg/m³ in the sample and the blank

Int - interference in analysis

Std - used as standard

ND - element not detectable using SSMS.

TABLE A-3. TRACE ELEMENT CONCENTRATION IN THE PARTICULATES FROM THE GASIFIER INLET AIR (SAMPLE DAY 4-4-78)

	Concentration (μg/m^3)		Concentration (μg/m^3)		Concentration (μg/m^3)
Al		Ho		Ru	
Sb	.12	In		Sm	
As	.57	I		Sc	.055
Ba	>.66	Ir		Se	.079
Be		Fe		Si	
Bi	> 1.	La	.16	Ag	
B		Pb	>.98	Na	
Br	.063	Li	.073	Sr	.42
Cd	.050	Lu		S	
Ca		Mg		Ta	
Ce	.2	Mn	>.92	Te	
Cs		Hg	ND	Tb	
Cl		Mo	.42	Tl	
Cr		Nd	.12	Th	
Co		Ni	.54	Tm	
Cu	.4	Nb	.02	Sn	.26
Dy		Os		Ti	.40
Er		Pd		W	
Eu		P		U	
F		Pt		V	.38
Gd		K		Yb	
Ga	>.99	Pr	.082	Y	.1
Ge	.024	Re		Zn	.6
Au		Rh		Zr	>.89
Hf		Rb	.075		

Sample was digested in HNO_3 and HCl prior to analysis.

Concentrations determined by SSMS except where indicated.

ND - element not detectable using SSMS.

All element concentrations reported <.014 μg/m^3.

*Heterogeneous.

TABLE A-4. TRACE ELEMENT CONCENTRATION IN THE PARTICULATES FROM THE GASIFIER INLET AIR (SAMPLE DAY 4-3-78)

	Concentration ($\mu g/m^3$)		Concentration ($\mu g/m^3$)		Concentration ($\mu g/m^3$)
Al		Ho		Ru	
Sb	.0088	In		Sm	
As	.09	I		Sc	.0075
Ba	>.066	Ir		Se	.01
Be		Fe		Si	
Bi	.0072	La	.012	Ag	
B		Pb	>.098	Na	
Br	.0083	Li	.0024	Sr	.049
Cd		Lu		S	
Ca		Mg		Ta	
Ce	.018	Mn	>.092	Te	
Cs		Hg	ND	Tb	
Cl		Mo	.0110	Tl	
Cr	>.0540	Nd		Th	
Co	.035	Ni	.028	Tm	
Cu	.071	Nb	≤ .0013	Sn	.023
Dy		Os		Ti	>.062
Er		Pd		W	
Eu		P		U	
F		Pt		V	.046
Gd		K		Yb	
Ga	>.099	Pr	.0033	Y	.012
Ge	.007	Re		Zn	.065
Au		Rh		Zr	.012
Hf		Rb	.0014		

Sample was digested in HNO_3 and HCl prior to analysis.

Concentrations determined by SSMS except where indicated.

ND - not detectable using SSMS.

All element concentrations not reported <.0012 $\mu g/m^3$.

TABLE A-5. TRACE ELEMENT CONCENTRATION IN THE PARTICULATES FROM THE GASIFIER INLET AIR (SAMPLE DAY 4-1-78)

	Concentration ($\mu g/m^3$)		Concentration ($\mu g/m^3$)		Concentration ($\mu g/m^3$)
Al		Ho		Ru	
Sb	.18	In		Sm	.216
As	2.76	I		Sc	.312
Ba		Ir		Se	.192
Be		Fe		Si	
Bi	.144	La	2.4	Ag	
B		Pb	4.14	Na	
Br		Li		Sr	3.3
Cd		Lu		S	
Ca		Mg		Ta	
Ce	1.8	Mn	> 5.52	Te	
Cs	>3.96	Hg	ND	Tb	
Cl		Mo	5.1	Tl	
Cr		Nd	.258	Th	
Co		Ni	1.74	Tm	
Cu	1.74	Nb	.024	Sn	
Dy		Os		Ti	> 3.72
Er		Pd		W	
Eu	.03	P		U	
F		Pt		V	3.48
Gd		K		Yb	
Ga	3.36	Pr	.12	Y	.78
Ge	.024	Re		Zn	2.52
Au		Rh		Zr	.54
Hf		Rb	.198		

Sample was digisted in HNO_3 and HCl prior to analysis.

Concentrations determined by SSMS except where indicated.

ND - not detectable using SSMS.

All element concentrations reported $<.024\ \mu g/m^3$.

TABLE A-6. TRACE ELEMENT CONCENTRATION IN THE ASH SLUICE WATER

	Concentration (µg/ml)		Concentration (µg/ml)		Concentration (µg/ml)
Al	>0.5	Ho	0.002	Ru	
Sb	0.004	In	Std	Sm	0.01
As	0.04	I	<0.001	Sc	0.007
Ba	≥10	Ir		Se	0.02
Be	<0.001	Fe	5	Si	≥10
Bi		La	0.05	Ag	0.002
B	0.001	Pb	0.02	Na	>1
Br	0.01	Li	0.4	Sr	3
Cd	0.003	Lu	0.001	S	>3
Ca	≥10	Mg	5	Ta	
Ce	0.1	Mn	0.01	Te	
Cs	0.003	Hg	ND	Tb	0.001
Cl	17	Mo	0.4	Tl	
Cr	0.5	Nd	0.01	Th	0.04
Co	0.04	Ni	0.03	Tm	<0.001
Cu	0.1	Nb	0.03	Sn	0.004
Dy	0.003	Os		Ti	≥10
Er	0.001	Pd		W	0.01
Eu	0.001	P	0.4	U	0.01
F	≃0.6	Pt		V	0.5
Gd	0.002	K	>6	Yb	0.002
Ga	0.04	Pr	0.01	Y	0.04
Ge	0.001	Re		Zn	0.07
Au		Rh		Zr	0.2
Hf		Rb	0.2		

Determined by SSMS except where indicated.

ND - not detectable using SSMS.

All element concentrations not reported <0.001 µg/ml.

Std - standard.

TABLE A-7. TRACE ELEMENT CONCENTRATION IN THE DRY ASH FROM THE GASIFIER

	Concentration (µg/g)		Concentration (µg/g)		Concentration (µg/g)
Al	≥1000	Ho	2	Ru	
Sb	0.5	In	Std	Sm	11
As	3	I	0.3	Sc	9
Ba	>1000	Ir		Se	2
Be	1	Fe	≥1000	Si	≥1000
Bi	18	La	160	Ag	1
B	13	Pb	12	Na	≥1000
Br	6	Li	≥240	Sr	490
Cd	0.4	Lu	0.3	S	≥1000
Ca	≥1000	Mg	≥1000	Ta	
Ce	180	Mn	69	Te	≤0.2
Cs	10	Hg	0.28*	Tb	0.6
Cl	8	Mo	15	Tl	0.3
Cr	190	Nd	34	Th	29
Co	23	Ni	62	Tm	0.2
Cu	200	Nb	35	Sn	2
Dy	3	Os		Ti	≥1000
Er	1	Pd		W	2
Eu	1	P	≥1000	U	32
F	≈59	Pt		V	200
Gd	2	K	≥1000	Yb	2
Ga	22	Pr	16	Y	56
Ge	1	Re	<0.1	Zn	18
Au		Rh		Zr	350
Hf	2	Rb	150		

Determined by SSMS except where indicated.

*Determined by atomic absorption spectrophotometry.

All element concentrations not reported <0.1 µg/g.

Std - used as the standard.

TABLE A-8. TRACE ELEMENT CONCENTRATION IN THE CYCLONE DUST

	Concentration (μg/g)		Concentration (μg/g)		Concentration (μg/g)
Al	>1000	Ho	1	Ru	
Sb	53	In	Std	Sm	11
As	85	I	24	Sc	7
Ba	>1000	Ir		Se	16
Be	0.8	Fe	>1000	Si	>1000
Bi	3	La	130	Ag	5
B	5	Pb	230	Na	>1000
Br	11	Li	160	Sr	270
Cd	2	Lu	0.3	S	> 1000
Ca	>1000	Mg	>1000	Ta	
Ce	99	Mn	570	Te	0.9
Cs	15	Hg	280*	Tb	0.6
Cl	100	Mo	57	Tl	22
Cr	58	Nd	110	Th	97
Co	10	Ni	47	Tm	0.2
Cu	68	Nb	52	Sn	39
Dy	2	Os		Ti	>1000
Er	0.9	Pd		W	5
Eu	1	P	>1000	U	45
F	≃240	Pt		V	150
Gd	1	K	>1000	Yb	2
Ga	220	Pr	35	Y	42
Ge	11	Re	≤0.1	Zn	>1000
Au	≤0.1	Rh		Zr	110
Hf	3	Rb	15		

Determined by SSMS except where indicated.

*Determined by atomic absorption spectrophotometry.

All element concentrations not reported <0.1 μg/g.

Std - used as the standard.

TABLE A-9. TRACE ELEMENT CONCENTRATION IN CYCLONE DUST LEACHATE

	Concentration (μg/ml)		Concentration (μg/ml)		Concentration (μg/ml)
Al	2	Ho		Ru	
Sb	0.03	In	Std	Sm	
As		I	0.1	Sc	≤0.002
Ba	0.7	Ir		Se	
Be	0.003	Fe	1*	Si	2
Bi		La	0.008	Ag	0.002
B	0.7	Pb	0.7	Na	>4
Br		Li	0.5	Sr	
Cd	0.005	Lu		S	>10.0
Ca	>10.0	Mg	7	Ta	
Ce	0.01	Mn	>10.0*	Te	
Cs	0.002	Hg	<0.0005 **	Tb	
Cl	>10.0	Mo	0.07*	Tl	≤0.001
Cr	0.004	Nd	0.005	Th	
Co	0.3	Ni	Int	Tm	
Cu	0.09	Nb	0.002	Sn	
Dy		Os		Ti	0.2
Er		Pd		W	
Eu		P	0.3	U	≤0.01
F	>10.0	Pt		V	0.002*
Gd		K	>10.0	Yb	
Ga		Pr	0.002	Y	0.004
Ge		Re		Zn	>10.0
Au		Rh		Zr	0.004
Hf		Rb			

Determined by SSMS except where indicated.

All element concentrations not reported < 0.002 μg/ml

**Determined by atomic absorption spectrophotometry

*Heterogeneous.

Int - Interference in analysis.

Std - used as the standard.

TABLE A-10. TRACE ELEMENT CONCENTRATION IN THE ASH LEACHATE

	Concentration (µg/ml)		Concentration (µg/ml)		Concentration (µg/ml)
Al	0.006	Ho		Ru	
Sb		In	Std	Sm	
As	0.004	I		Sc	
Ba	0.1	Ir		Se	≤0.001
Be		Fe	0.01	Si	0.2
Bi		La	≤0.002	Ag	0.005
B	0.02	Pb	0.008	Na	>1
Br	0.002	Li	0.03	Sr	0.06
Cd	0.001	Lu		S	0.3
Ca	0.099	Mg	0.036	Ta	
Ce		Mn	0.005	Te	
Cs		Hg	ND	Tb	
Cl	0.16	Mo	0.02	Tl	
Cr	0.002	Nd		Th	
Co	0.001	Ni	Int	Tm	
Cu	0.008	Nb	0.001	Sn	0.001
Dy		Os		Ti	≤0.01
Er		Pd		W	
Eu		P	0.1	U	0.007
F	≃0.06	Pt		V	0.003
Gd		K	>6	Yb	
Ga	0.001	Pr		Y	
Ge		Re		Zn	4
Au		Rh		Zr	0.03
Hf		Rb	0.002		

Determined by SSMS.

ND - not detectable using SSMS.

All element concentrations not reported <0.001 µg/ml.

Std - used as the standard.

TABLE A-11. TRACE ELEMENT CONCENTRATION IN THE WELLMAN-GALUSHA GASIFIER JACKET WATER

	Concentration (μg/ml)		Concentration (μg/ml)		Concentration (μg/ml)
Al	>1	Ho		Ru	
Sb	0.07	In	Std	Sm	
As	0.04	I	0.6	Sc	≤0.001
Ba	0.5	Ir		Se	0.02
Be		Fe	9	Si	≥10
Bi		La	0.01	Ag	0.004
B	0.005	Pb	0.2	Na	3
Br	0.3	Li	0.001	Sr	0.5
Cd	0.004	Lu		S	>8
Ca	≥10	Mg	≥10	Ta	
Ce	0.007	Mn	0.3	Te	
Cs		Hg	ND	Tb	
Cl	3	Mo	0.01	Tl	
Cr	0.04	Nd		Th	
Co	0.004	Ni	0.01	Tm	
Cu	0.07	Nb	0.02	Sn	0.005
Dy		Os		Ti	0.3
Er		Pd		W	
Eu		P	0.9	U	0.02
F	≃3	Pt		V	0.01
Gd		K	≥10	Yb	
Ga	0.004	Pr	0.003	Y	0.004
Ge	0.007	Re		Zn	3
Au	≤0.003	Rh		Zr	0.008
Hf		Rb	0.02		

Determined by SSMS.

ND - not detectable using SSMS.

All element concentrations not reported <0.001 μg/ml.

Std - used as standard.

TABLE A-12. TRACE ELEMENT CONCENTRATION IN THE SERVICE WATER USED AT THE LOW-BTU GASIFICATION FACILITY

	Concentration (µg/ml)		Concentration (µg/ml)		Concentration (µg/ml)
Al	0.01	Ho		Ru	
Sb		In	Std	Sm	
As	0.006	I	0.001	Sc	≤0.001
Ba	0.2	Ir		Se	<0.003
Be		Fe	0.2	Si	0.6
Bi		La	0.002	Ag	0.04
B	0.002	Pb	0.07	Na	>2
Br	0.03	Li	0.001	Sr	0.1
Cd	0.001	Lu		S	1
Ca	≥10	Mg	≥10	Ta	
Ce	0.001	Mn	0.02	Te	
Cs		Hg	ND	Tb	
Cl	0.5	Mo	0.004	Tl	
Cr	≤0.02	Nd		Th	
Co	≤0.001	Ni	0.02	Tm	
Cu	0.05	Nb		Sn	
Dy		Os		Ti	≤0.02
Er		Pd		W	
Eu		P	0.2	U	0.008
F	≃0.3	Pt		V	0.002
Gd		K	≥10	Yb	
Ga	<0.001	Pr		Y	0.001
Ge		Re		Zn	0.8
Au		Rh		Zr	0.001
Hf		Rb	0.003		

Determined by SSMS.

ND - not detectable using SSMS

All element concentrations not reported <0.002 µg/ml

Std - used as the standard

TABLE A-13. TRACE ELEMENT CONCENTRATION IN THE TEST BURNER FLUE GAS (SASS CONDENSATE, XAD-2, AND IMPINGER SAMPLES)

	Concentration ($\mu g/m^3$ @ 25°C)		Concentration ($\mu g/m^3$ @ 25°C)		Concentration ($\mu g/m^3$ @ 25°C)
Al	≥130	Ho		Ru	
Sb	1.0	In	Std	Sm	
As	18	I	2.1	Sc	≤0.63
Ba	16	Ir		Se	12.0
Be		Fe	>590	Si	120
Bi		La	1.4	Ag	7.4
B	230	Pb	4.2	Na	≥130
Br	2.8	Li	0.035	Sr	4.0
Cd	0.70	Lu		S	320
Ca	780	Mg	110	Ta	
Ce	0.63	Mn	27	Te	≤0.1
Cs	1.0	Hg	ND	Tb	
Cl	490	Mo	68	Tl	
Cr	>680	Nd		Th	
Co	<7.3	Ni	290.0	Tm	
Cu	5.3	Nb	2.2	Sn	7.2
Dy		Os		Ti	≤15
Er		Pd		W	1.0
Eu		P	63	U	4.4
F	≃32	Pt		V	3.0
Gd		K	440	Yb	
Ga	0.56	Pr	0.35	Y	0.2
Ge	0.35	Re		Zn	28
Au		Rh		Zr	1.0
Hf		Rb	<0.03		

Gas Flow - 174 scfm.

Concentrations determined by SSMS.

ND- not detectable using SSMS.

All element concentrations not reported ≤0.1.

Std - used as the standard.

TABLE A-14. HYDROCARBON (C_1-C_6) CONTENT OF THE PRODUCT LOW-BTU GAS

Date Sampled	Component Concentration C_1 (vppm)	 C_2 (vppm)	 C_3 (vppm)
3/28	2330.2	1.3	1.5
3/29	2109.3	ND	ND
	1840.5	ND	ND
	1791.0	ND	ND
	1741.0	ND	ND
3/30	2007.3	ND	6.6
	2373.6	2.3	6.1
	2051.4	1.7	2.2
3/31	1635.5	ND	4.4
	1958.6	2.0	4.7
4/1	1803.2	ND	3.5
	1809.0	0.3	3.9
	1808.5	ND	4.1
	1688.5	ND	3.3
4/2	1890.8	ND	4.1
	1820.0	0.4	4.8
	1816.7	0.4	4.4
4/3	1930.6	ND	8.4
	1954.4	ND	2.2
	1912.4	ND	2.4

Analyzed by gas chromatography from grab samples.

ND - Not detected.

C_4-C_6 were not detected.

TABLE A-15. DAILY AVERAGES OF FIXED GASES AND THE HHV FOR THE PRODUCT LOW-BTU GAS

Date Sampled	3/27	3/28	3/29	3/30	3/31	4/1	4/2	4/3
No. of Samples Collected	1	4	4	2	2	3	5	3
Component	Daily Averages (Vol %)							
CO_2	5.77	5.64	5.45	5.40	5.40	5.31	5.54	5.63
H_2	15.95	15.78	16.59	16.64	16.35	16.39	16.33	16.43
O_2	0.85	0.79	0.90	0.78	0.93	0.85	1.06	1.01
N_2	52.00	51.69	51.31	51.28	51.40	51.46	51.91	51.58
CH_4	0.23	0.21	0.24	0.24	0.27	0.23	0.22	0.21
CO	25.20	25.89	25.51	25.66	25.65	25.76	24.94	25.14
HHV*(MJ/dry m^3)	5.03	5.07	5.14	5.18	5.14	5.14	5.03	5.07

Analyzed by gas chromatography from grab samples.

Average moisture content of gas was 5.94%.

*HHV calculated based on H_2, CO and CH_4 concentrations.

TABLE A-16. SULFUR SPECIES (H_2S, COS, SO_2, CS_2) CONCENTRATION IN THE PRODUCT LOW-BTU GAS

Sample Date	Component Concentration (vppm)			
	H_2S	COS	SO_2	CS_2
3/28	-	89.96	-	0.7022
	357.6	77.76	-	-
	551.8	91.40	-	0.5130
	-	89.71	-	1.039
	-	90.73	-	1.131
3/29	404.3	95.37	-	-
	562.8	104.4	-	<0.5
	-	-	7.017	1.318
	-	93.09	6.099	<0.5
3/30	727.0	94.14	9.859	-
	653.6	97.48	11.25	1.364
	683.6	99.58	10.66	-
3/31	612.4	88.88	-	-
	-	-	11.92	0.9294
	633.5	91.08	14.89	1.017
	620.8	93.92	13.44	0.7650
	740.5	94.35	16.76	0.6038
4/1	766.2	91.55	15.49	1.102
	643.3	94.83	24.19	0.8847
	692.0	97.96	76.64	-
	842.2	100.1	76.80	-
	863.6	103.3	74.84	1.519
4/2	658.5	99.38	8.812	0.9264
	576.6	107.1	7.205	<0.5
4/3	711.9	94.60	10.03	0.8875
	652.3	86.79	4.606	<0.5
	699.2	87.26	-	-
	287.2	61.07	4.760	<0.5

- not determined

Analyzed by gas chromatography from grab samples.

TABLE A-17. TOTAL SULFUR DETERMINATIONS IN THE PRODUCT LOW-BTU GAS

Sample Date	Sulfur Concentration (vppm)	Sulfur Mass Flow
3/30	833	10.30
3/31	699	8.73
	667	8.33
	750	9.36
4/3	743	9.89
	658	8.76
	727	9.68
4/7	577	0.108*
	649	0.122*

*Product gas to the test burner

TABLE A-18. CN^-, SCN^-, NH_3, $Ni(CO)_4$, $Fe(CO)_5$ CONCENTRATION IN PRODUCT LOW-BTU GAS

	Component Concentration				
Sample Date	CN^- (vppm)	SCN^- (vppm)	NH_3 (vppm)	$Ni(CO)_4$ ($\mu g/m^3$ @ 25°C)	$Fe(CO)_5$ ($\mu g/m^3$ @ 25°C)
3/31	<3.0	6.4	247	41	228
	43.1	5.7	190	23	82
			130		
4/3	53.4	9.8	160	10	3
	28.5	10.9	204		
			127		
4/7*	45.3*	10.2*	217*		
	16.4*	13.1*	137*		
	45.3*	6.7*	251*		
	35.2*	15.8*	261*		
	40.6*	4.3*	221*		

Analyzed from impinger samples.

*Product gas to test burner.

TABLE A-19. PARTICULATE SIZE DISTRIBUTION IN THE PRODUCT LOW-BTU GAS

	Particulates Collected (g)	% of Particulates Collected	Estimated Particle Diameter (μm)		
			Aerodynamic Impaction	Aerodynamic	Stokes
Cyclone	349.39	99.70	>6.80		
Stage 1	0.86	0.24	3.95	3.78	3.77
Stage 2	0.04	0.01	2.38	2.22	2.21
Stage 3	0.04	0.01	1.61	1.45	1.44
Stage 4	0.02	0.01	1.02	0.88	0.86
Stage 5	0.03	0.01	0.67	0.54	0.52
Stage 6	0.07	0.02	<0.67	<0.54	<0.52
	350.45	100.00			
Cyclone	76.06	94.38	>15.0		
Stage 1	2.54	3.15	7.91	7.73	7.73
Stage 2	0.27	0.34	4.76	4.59	4.59
Stage 3	0.15	0.19	3.22	3.06	3.05
Stage 4	0.12	0.15	2.05	1.89	1.88
Stage 5	0.06	0.07	1.35	1.19	1.18
Stage 6	1.39	1.72	<1.35		
	80.59	100.00			

TABLE A-20. COMPARISON OF COAL HOPPER GAS AND PRODUCT LOW-BTU GAS COMPOSITIONS

	Sample Collection Date			
	3/31	4/1	4/3	4/3
Component	Coal Hopper Gas Composition			Product Low-Btu Gas Composition
CO_2 (vol%)	4.58	4.41	4.69	5.63
H_2 (vol%)	15.64	14.19	13.60	16.43
O_2 (vol%)	1.88	3.16	4.01	1.01
N_2 (vol%)	52.86	54.23	55.17	51.58
CH_4 (vol%)	0.25	0.21	0.20	0.21
CO (vol%)	24.79	23.80	22.26	25.14
H_2S (vppm)			287.2	587.6
COS (vppm)			61.1	82.4
SO_2 (vppm)			4.8	6.5
CS_2 (vppm)			<0.5	<0.6
CN^- (vppm)			ND	41.0
SCN^- (vppm)			ND	10.4
NH_3 (vppm)			ND	164
$Fe(CO)_5$ (μg/m^3 @25°C)			15.5	104*
$Ni(CO)_4$ (μg/m^3 @25°C)			ND	25*
Particulates			ND	

*Average concentration of 3/31 and 4/3 samples

ND: Not detected

Coal Hopper Gas Flow Rate = 4.5 scfm (0.13 m^3/min @ 25°C)

TABLE A-21. ESTIMATED CONCENTRATION AND COMPONENT FLOW RATE FOR THE POKEHOLE GASES

Component	Estimated Concentration[a] (vol %)	Estimated Concentration[a] ($\mu g/m^3$)	Estimated Flow Rate[b] (μg/sec @25°C)
CO_2	5.63	103.6×10^6	18,700
H_2	16.43	13.7×10^6	2,500
O_2	1.01	13.5×10^6	2,400
N_2	51.58	604.0×10^6	109,100
CH_4	0.21	1.4×10^6	250
CO	25.14	294.4×10^6	53,200
H_2S	0.0588	0.836×10^6	150
COS	0.0082	0.206×10^6	40
SO_2	0.0006	0.016×10^6	3
CS_2	<0.00006	$<0.002 \times 10^6$	<0.4

[a] Average product low-Btu gas composition for sample day 4/3.

[b] Average flow rate of pokehole gases (pokehole valve closed and with poke rod inserted) = 22.8 scfh (0.65 m^3/h @25°C)

TABLE A-22. TEST BURNER FLUE GAS COMPOSITION

Component	Average Concentration
CO_2 (vol%)	9.5
O_2 (vol%)	10.8
N_2 (vol%)	79.7
C_1 (vppm)	0.4
C_2 (vppm)	ND
C_3 (vppm)	ND
H_2S (vppm)	ND
COS (vppm)	ND
SO_2 (vppm)	491
CS_2 (vppm)	ND
Total S (vppm)	199
NO_x (vppm)	267
CN^- (vppm)	<3
SCN^- (vppm)	2
NH_3 (vppm)	<5
$Fe(CO)_5$ (vppb)	17
$Ni(CO)_4$ (vppb)	3
Total Organics (μ/m³ @ 25°C)	1910

Flue gas flow rate: 174 scfm (4.87 m³/min @ 25°C)

ND: Not detected.

TABLE A-23. PRODUCT GAS ORGANIC EXTRACTS

TCO = 680 μg/m^3 @ 25°C
Grav = 6310 μg/m^3
Total = 6990 μg/m^3

Organic Compounds Identified by GC/MS

Compound	Concentration, μg/m^3 @ 25°C
Acenaphthylene	6
Anthracene/Phenanthrene	25
Fluoranthene	6
Fluorene	6
Naphthalene	75
Phenol	52
Methyl Phenols ≥2 isomers	27
Dimethyl Phenols ≥2 isomers	11
Bis-(2-Ethylhexyl) Phthalate	8
Pyrene	15
Sulfur	210

TABLE A-24. PRODUCT GAS PARTICULATES ORGANIC EXTRACTS

TCO = 4700 μg/g
Grav = 20,400 μg/g
Total = 25,100 μg/g

Organic Compounds Identified by GC/MS

Compound	Concentration, μg/g
Anthracene/Phenanthrene	20
Chrysene/Benzanthracene	7
Fluoranthene	7
Phenols	ND
Bis-(2-Ethylhexyl) Phthalate	200
Di-N-Butyl Phthalate	20
Diethyl Phthalate	20
Pyrene	20
Sulfur	4000

ND: not detected (<0.7 μg/g)

TABLE A-25. ORGANIC EXTRACTS OF GASIFIER INLET AIR PARTICULATES (SAMPLE DAY 4/3/78)

TCO = 118 μg/g

Grav = 124 μg/g

Total = 242 μg/g

Organic Compounds Identified by GC/MS

Compound	Concentration, μg/g
Chloronaphthalene	0.3
Naphthalene	0.7
Phenols	ND
Bis-(2-Ethylhexyl) Phthalate	1.0
Di-N-Butyl Phthalate	0.7
Diethyl Phthalate	2.1
Sulfur	ND

ND: not detected (<0.03 μg/g)

TABLE A-26. ORGANIC EXTRACT OF GASIFIER INLET AIR PARTICULATES (SAMPLE DAY 4/1/78)

TCO = 670 μg/g

Grav = 90 μg/g

Total = 760 μg/g

Organic Compounds Identified by GC/MS

Compound	Concentration, μg/g
Anthracene/Phenanthrene	0.50
Fluorene	0.25
Naphthalene	1.8
Phenols	ND
Bis-(2-Ethylhexyl) Phthalate	0.25
Butyl Benzyl Phthalate	0.50
Di-N-Butyl Phthalate	0.25
Diethyl Phthalate	1.0
Sulfur	ND

ND: not detected (<0.03 μg/g)

TABLE A-27. ASH SLUICE WATER ORGANIC EXTRACTS

TCO = 40,000 μg/ℓ
Grav = 6500 μg/ℓ
Total = 46,500 μg/ℓ

Organic Compounds Identified by GC/MS

Compound	Concentration, μg/ℓ
Phenol	ND
Bis-(2-Ethylhexyl) Phthalate	33
Di-N-Butyl Phthalate	7
Sulfur	ND

ND: not detected (<0.7 μg/ℓ)

TABLE A-28. DRY GASIFIER ASH ORGANIC EXTRACTS

TCO = 13 μg/g

Grav = 103 μg/g

Total = 116 μg/g

Organic Compounds Identified by GC/MS

Compound	Concentration, μg/g
Phenol	ND
Bis-(2-Ethylhexyl) Phthalate	0.58
Di-N-Butyl Phthalate	0.08
Diethyl Phthalate	0.05
Sulfur	77.0

ND: not detected (<0.0005 μg/g)

TABLE A-29. WET GASIFIER ASH ORGANIC EXTRACTS

TCO = 33 μg/g

Grav = 63 μg/g

Total = 96 μg/g

Organic Compounds Identified by GC/MS

Compound	Concentration, μg/g
Phenols	ND
Bis-(2-Ethylhexyl) Phthalate	0.03
Di-N-Butyl Phthalate	0.34
Diethyl Phthalate	0.15
Sulfur	30.0

ND: not detected (<0.001 μg/g)

TABLE A-30. CYCLONE DUST ORGANIC EXTRACTS

TCO = 42 μg/g
Grav = 743 μg/g
Total = 785 μg/g

Organic Compounds Identified by GC/MS

Compound	Concentration, μg/g
Anthracene/Phenanthrene	0.1
Fluorene	0.1
Naphthalene	0.4
Phenols	ND
Bis-(2-Ethylhexyl) Phthalate	2.0
Di-N-Butyl Phthalate	0.2
Diethyl Phthalate	0.2
Sulfur	160

ND: not detected (<0.01 μg/g)

TABLE A-31. ASH LEACHATE ORGANIC EXTRACTS

TCO = 31,500 μg/ℓ

Grav = 4700 μg/ℓ

Total = 36,200 μg/ℓ

Organic Compounds Identified by GC/MS

Compound	Concentration, μg/ℓ
Phenols	ND
Bis-(2-Ethylhexyl) Phthalate	21
Di-N-Butyl Phthalate	21
Diethyl Phthalate	52
Sulfur	ND

ND: not detected (<1.0 μg/ℓ)

TABLE A-32. COMBUSTOR GAS COMBINED ORGANIC MODULE EXTRACTS

TCO = 950 μg/m^3 @ 25°C

Grav = 950 μg/m^3

Total = 1900 μg/m^3

Organic Compounds Identified by GC/MS

Compounds	Concentration, μg/m^3 @ 25°C
Anthracene/Phenanthrene	0.4
Fluoranthene	0.4
Naphthalene	1.2
Phenol	6.9
Bis-(2-Ethylhexyl) Phthalate	4.7
Di-N-Butyl Phthalate	0.6
Pyrene	0.8
Benzo(a)pyrene	0.4
Sulfur	ND

ND: not detected (<0.02 μg/m^3 @ 25°C)

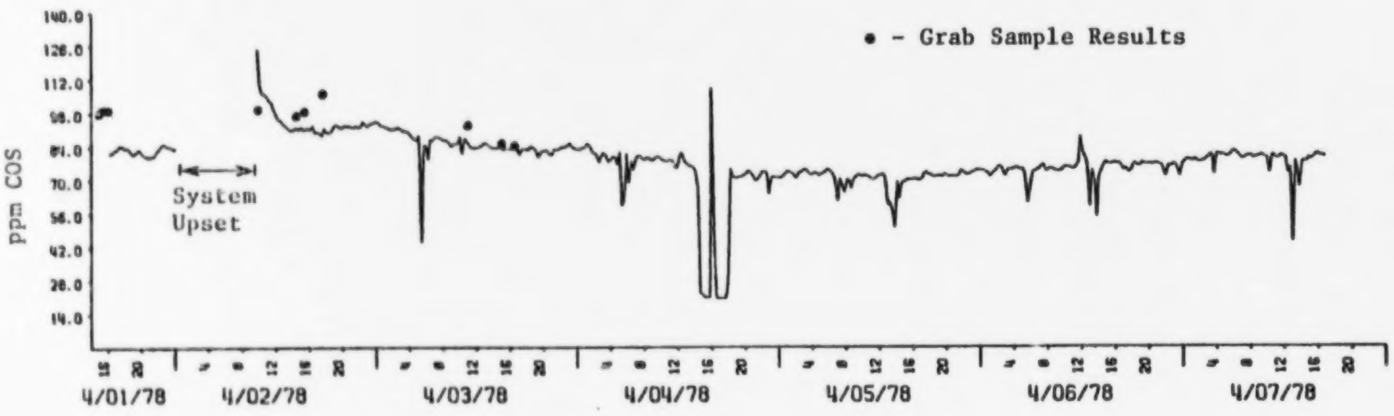
TABLE A-33. LIST OF CONTINUOUS MONITORING DATA IN APPENDIX

Monitoring by Radian

COS concentration in product gas, ppm
H_2S concentration in product gas, ppm
CS_2 concentration in product gas, ppm
SO_2 concentration in product gas, ppm
NH_3 concentration in product gas, ppm
CH_4 concentration in product gas, %

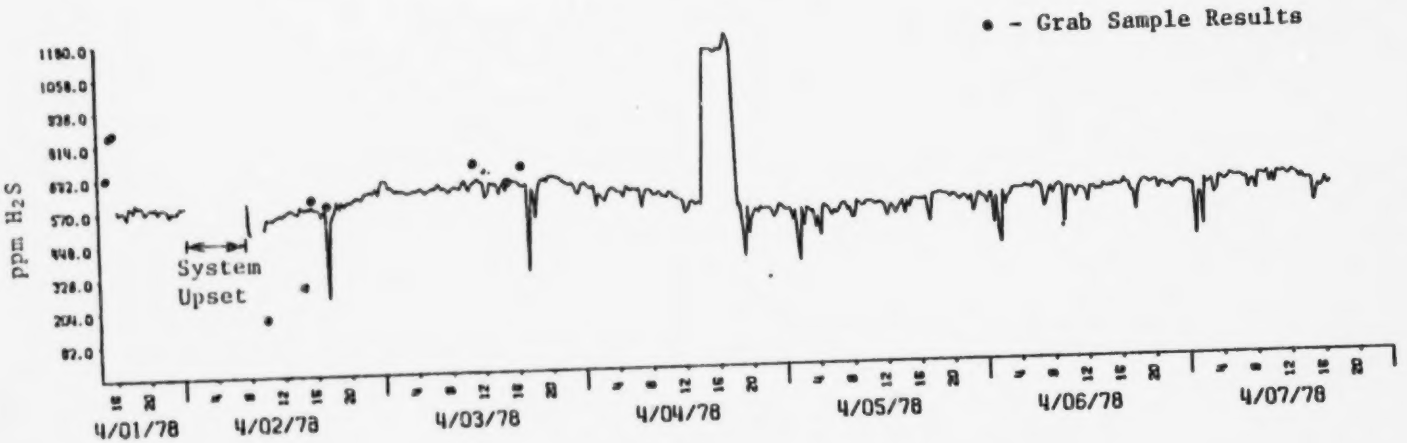
Monitoring by Acurex

Heating value of product gas
CO concentration in product gas, %
CO_2 concentration in product gas, %
CH_4 concentration in product gas, %
Temperature of product gas
Temperature of inlet jacket water
Temperature of outlet jacket water
Temperature of gasifier saturated inlet air
Flow rate of inlet jacket water
Orifice reading for product gas flow rate
Orifice reading for flow rate across gasifier
Pressure drop across gasifier



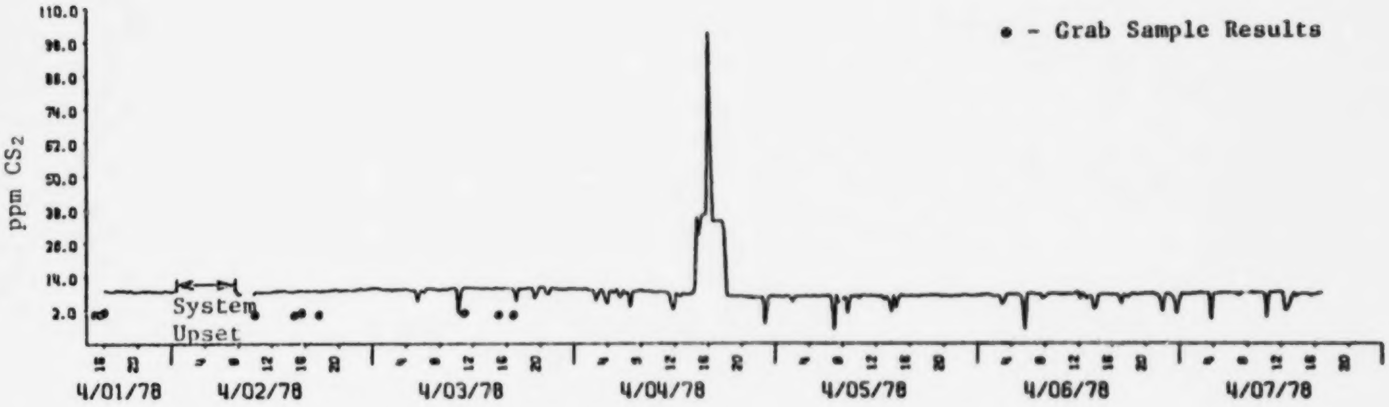
Note: Monitored by Radian Corporation

Figure A-1. On-Line Gas Chromatograph Results - Carbonyl Sulfide Concentrations in the Product Gas, ppm.



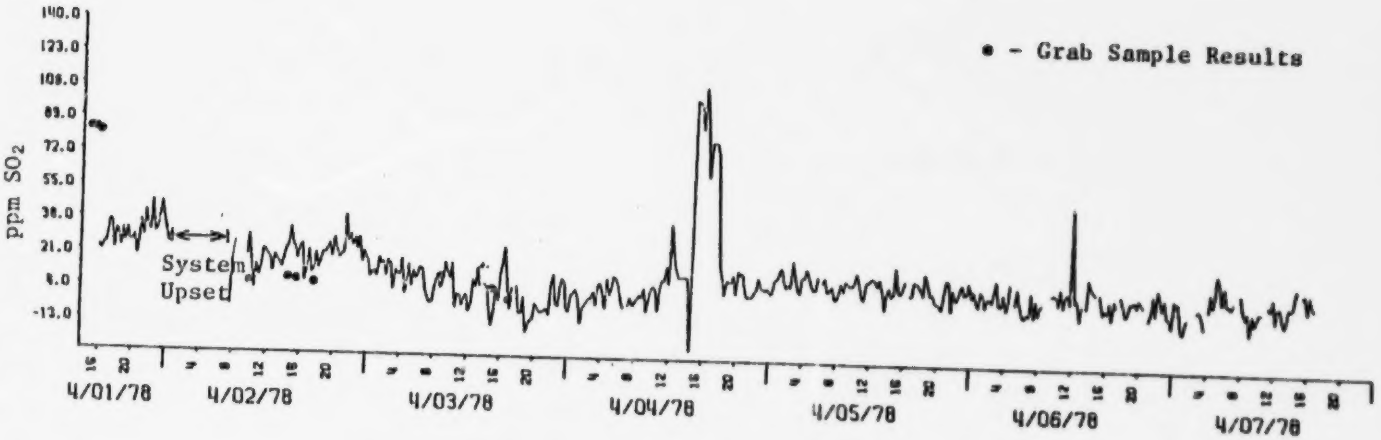
Note: Monitored by Radian Corporation

Figure A-2. On-Line Gas Chromatograph Results - Hydrogen Sulfide Concentration in the Product Gas, ppm.



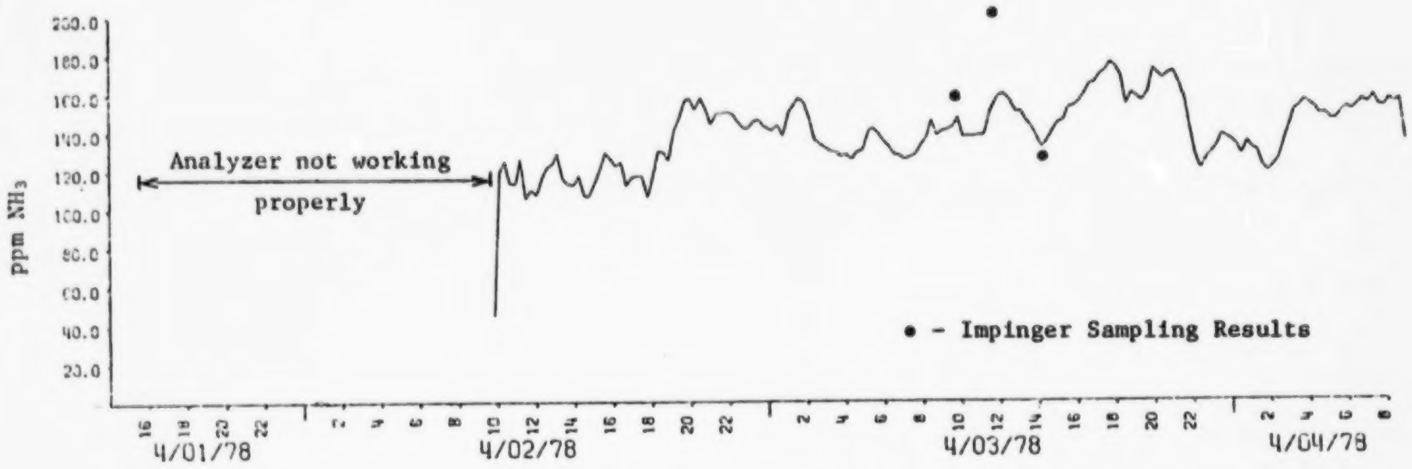
Note: Monitored by Radian Corporation

Figure A-3. On-Line Gas Chromatograph Results - Carbon Disulfide Concentration in the Product Gas, ppm.



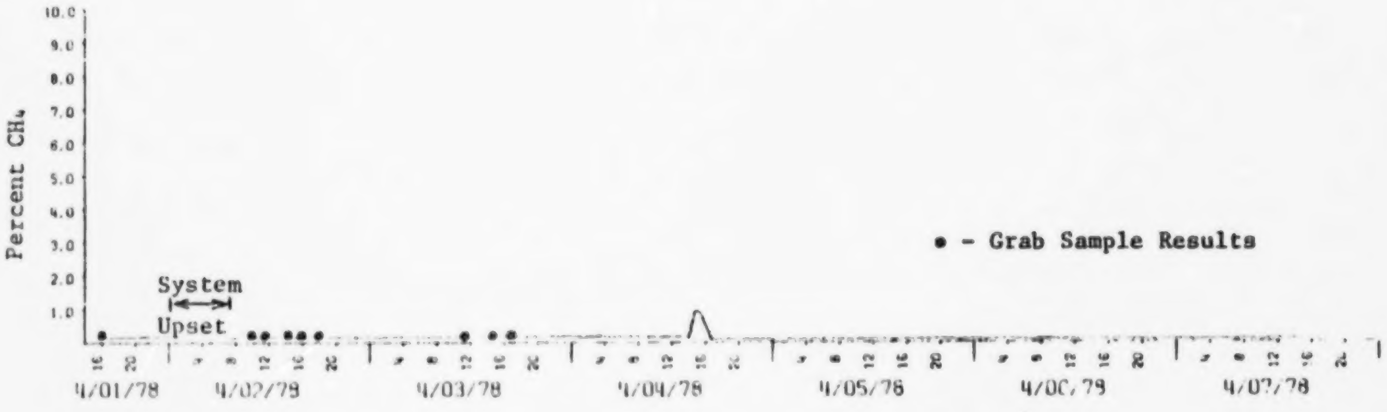
Note: Monitored by Radian Corporation.

Figure A-4. On-Line Gas Chromatograph Results - Sulfide Dioxide Concentration in the Product Gas, ppm.



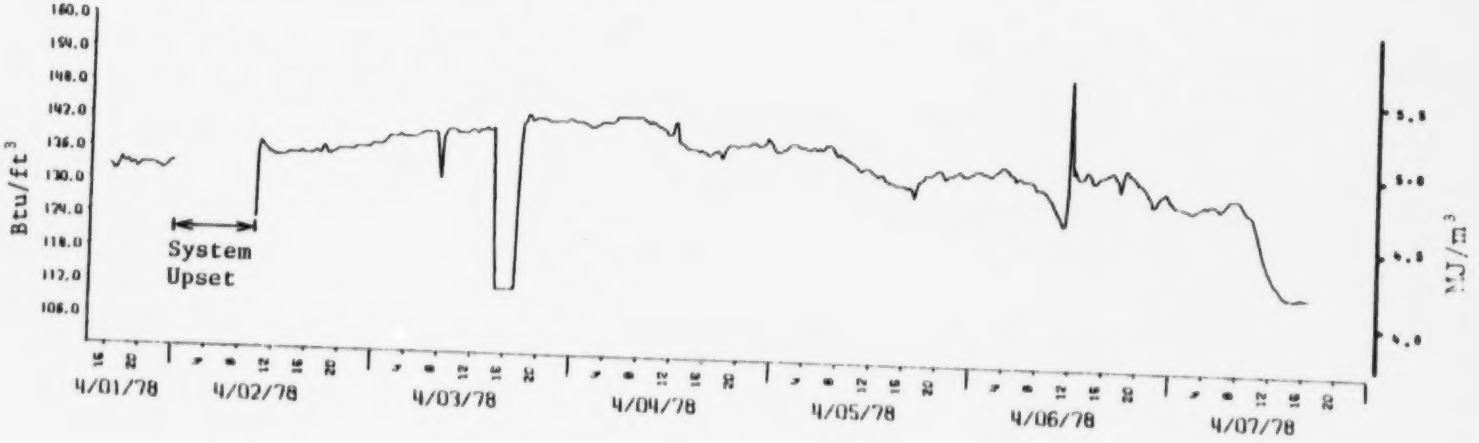
Note: Monitored by Radian Corporation

Figure A-5. On-Line Gas Chromatograph Results - Ammonia Concentration in the Product Gas, ppm.



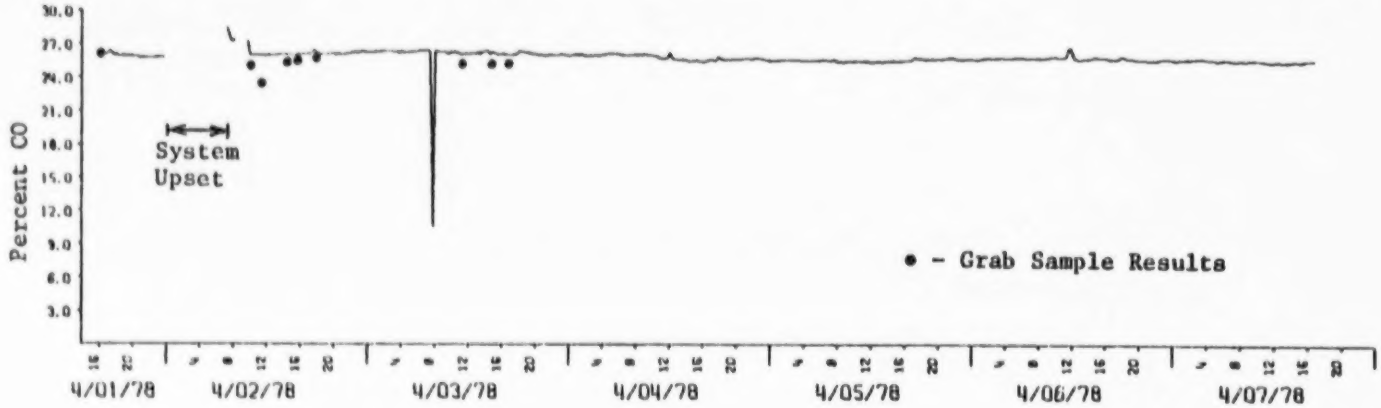
Note: Monitored by Radian Corporation

Figure A-6. On-Line Gas Chromatograph Results - Methane Concentration in the Product Gas, %.



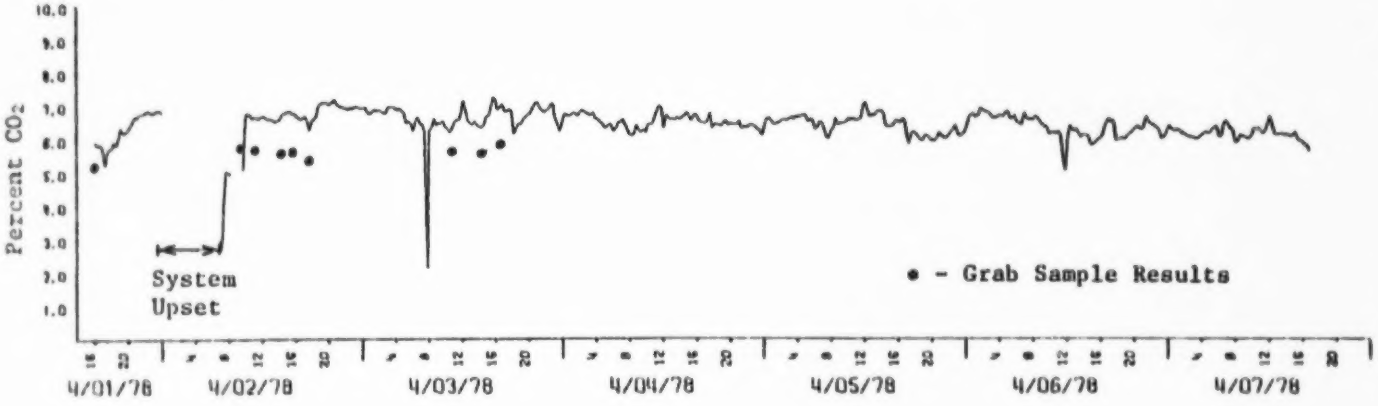
Note: Monitored by Acurex Corporation

Figure A-7. Heating Value of Product Gas



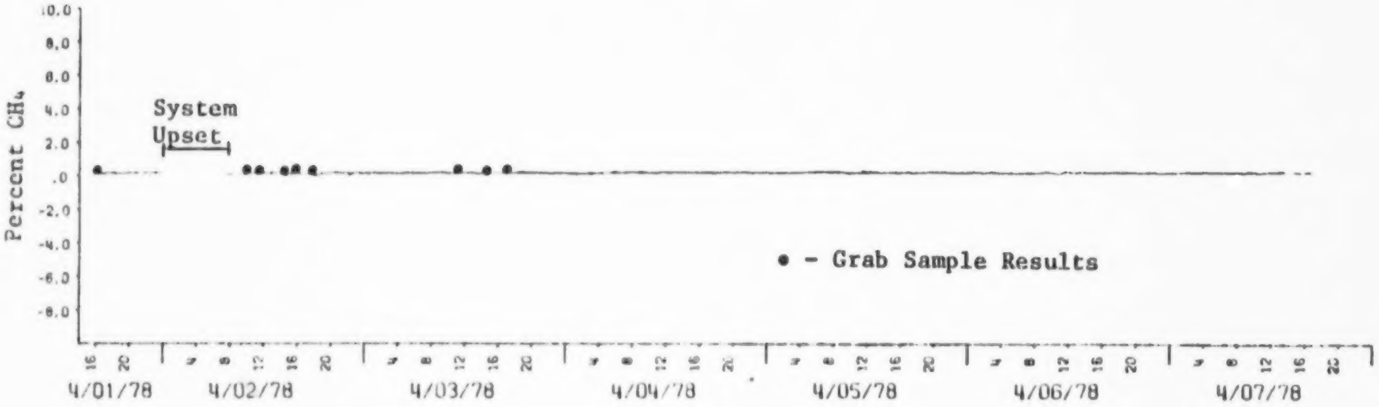
Note: Monitored by Acurex Corporation

Figure A-8. On-Line Gas Chromatograph Results - Carbon Monoxide Concentration in Product Gas, %



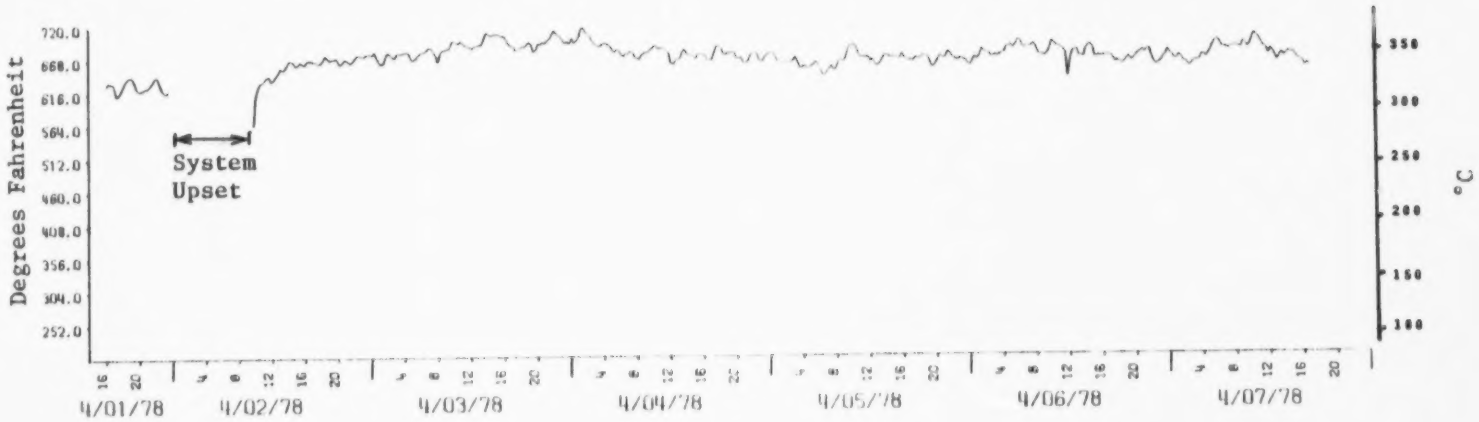
Note: Monitored by Acurex Corporation

Figure A-9. On-Line Gas Chromatograph Results - Carbon Dioxide Concentration in Product Gas, %



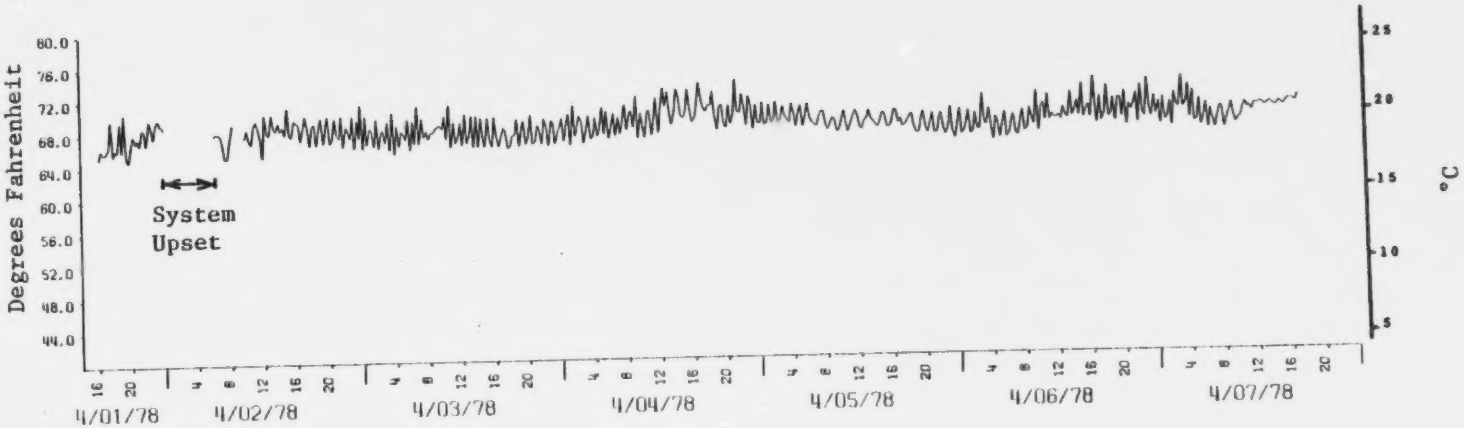
Note: Monitored by Acurex Corporation

Figure A-10. On-Line Gas Chromatograph Results - Methane Concentration in Product Gas, %



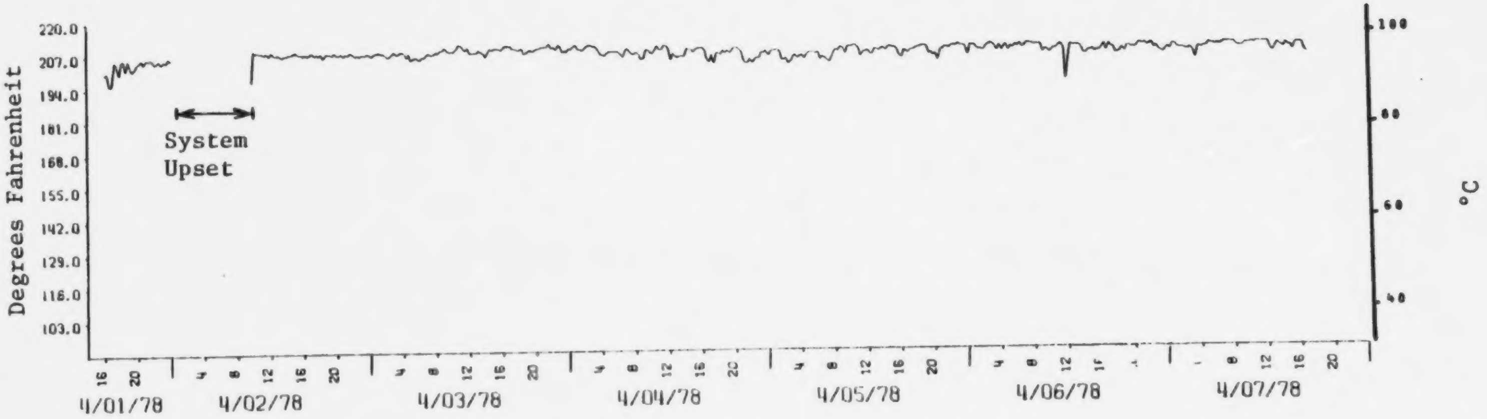
Note: Monitored by Acurex Corporation

Figure A-11. Temperature of Product Gas



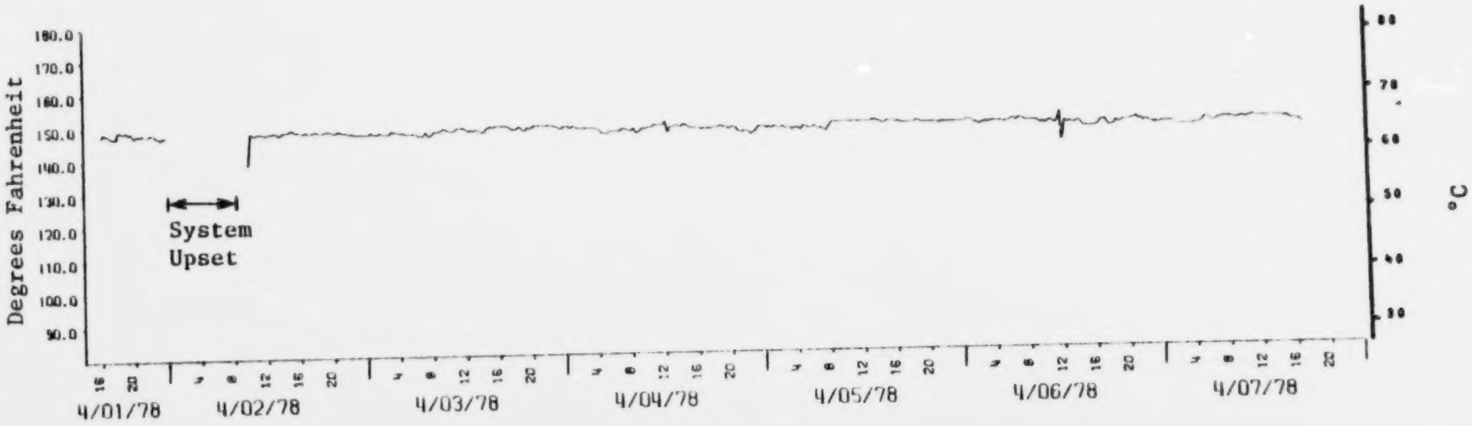
Note: Monitored by Acurex Corporation

Figure A-12. Temperature of Inlet Jacket Water



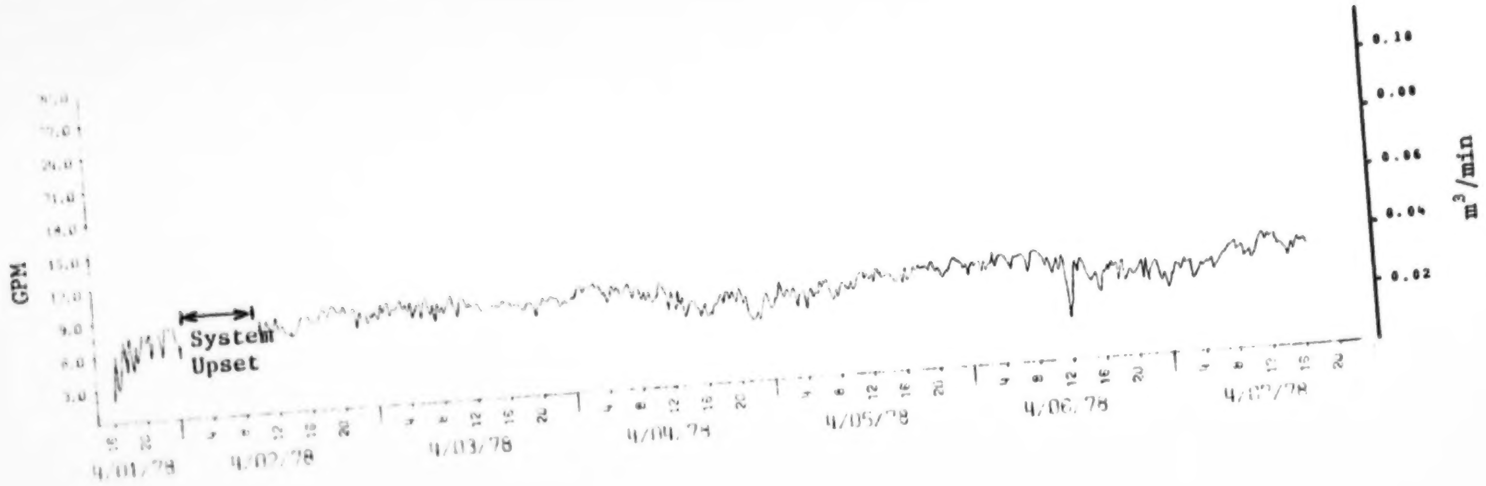
Note: Monitored by Acurex Corporation

Figure A-13. Temperature of Outlet Jacket Water



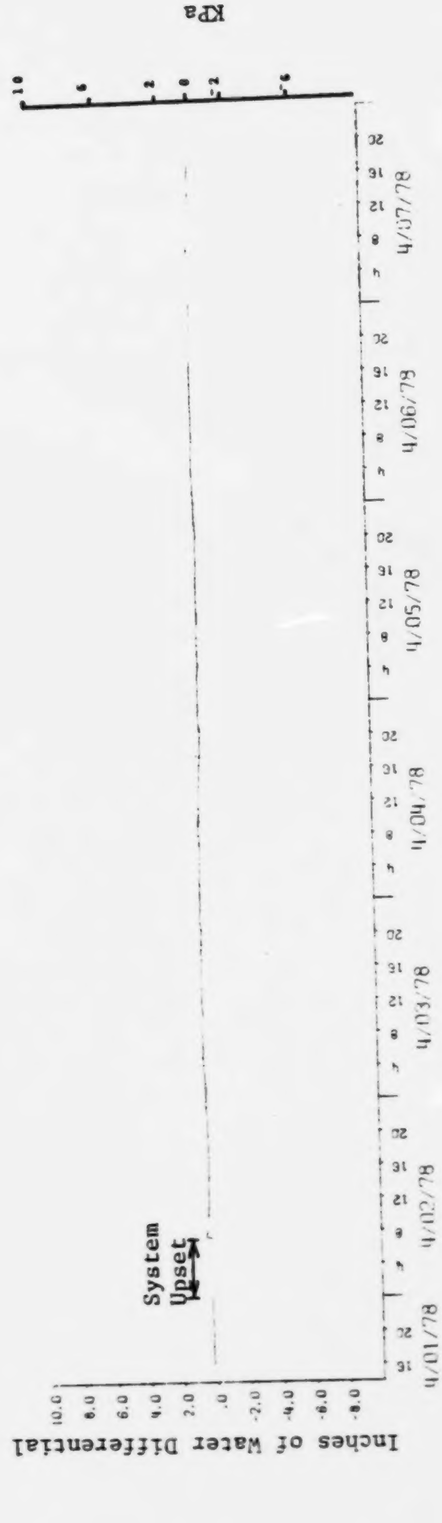
Note: Monitored by Acurex Corporation

Figure A-14. Temperature of Gasifier Saturated Inlet Air



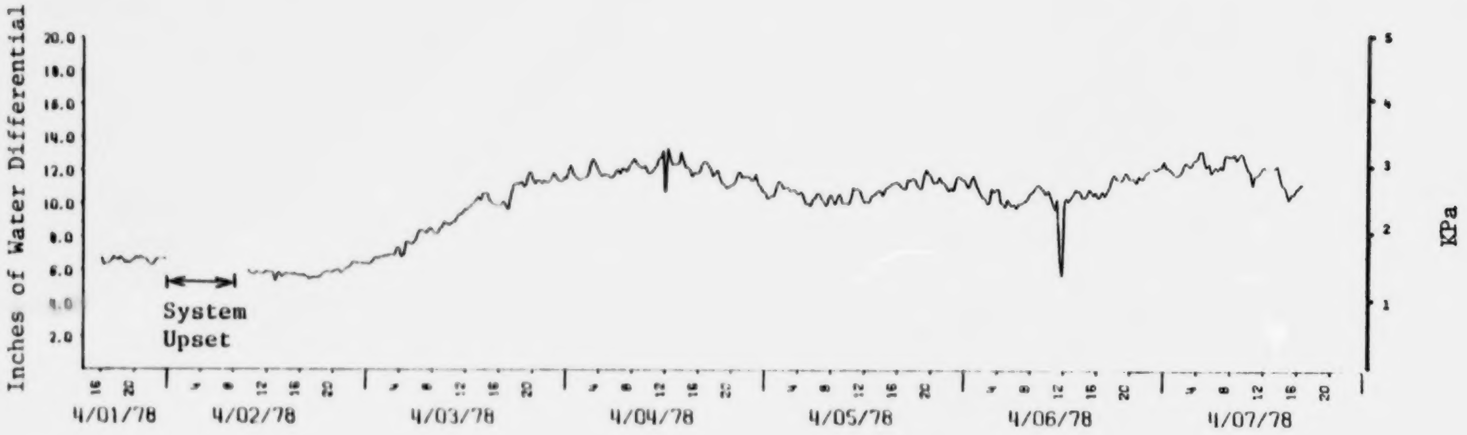
Note: Monitored by Acurex Corporation

Figure A-15. Flow Rate of Inlet Jacket Water



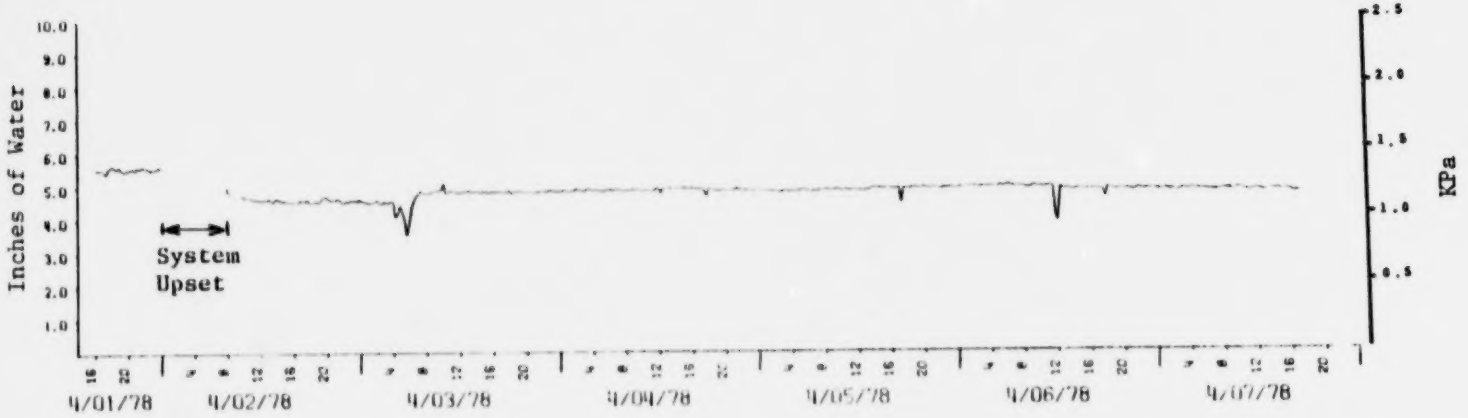
Note: Monitored by Acurex Corporation

Figure A-16. Orifice Reading for Product Gas Flow Rate



Note: Monitored by Acurex Corporation

Figure A-17. Orifice for Flow Rate Across Gasifier



Note: Monitored by Acurex Corporation

Figure A-18. Pressure Drop Across Gasifier

TABLE A-34. BIOASSAY TEST RESULTS - GLEN-GERY GASIFICATION FACILITY

	Coal Feed	Gasifier Ash*	Ash Sluice Water*	Ash Leachate	Cyclone Dust*	Dust Leachate
HEALTH TESTS						
1. AMES[a]	Neg[b]	Neg	Neg	Neg	Neg	Neg
2. Cytotoxicity						
WI-38, EC-50 (cell count, μℓ/mℓ of culture)			>600	>600		500
RAM, EC-50 (cell count, μg/mℓ of culture)	>1000	>1000			>1000	
3. Rodent Acute Toxicity	Low	Low	Low	Low	Low	
LD-50 (g sample/kg rat)	>10	>10	>10	>10	>10	
ECOLOGICAL TESTS						
Soil Microcosm		**			**	

* Indicates a plant waste stream.

a: AMES tests were also run on Product Gas and Combustor Flue Gas particulates and XAD-2 resin extracts. All tests results were negative.

b: Mutagenic activity was observed in one sample of coal; however, this observation was not repeated in any other coal sample.

**: Gasifier ash was clearly more toxic than cyclone dust.

TABLE A-35. RADIOACTIVE DISINTEGRATION

	Gross α Disintegration / min·g			Gross β Disintegration / min·g		
Coal Feed	4.2	±	1.3	0.0	±	7.1
Dry Ash	9.5	±	1.3	0.0	±	7.6
Cyclone Dust	8.4	±	2.4	6.0	±	9
Product Gas Particulates	620	±	44	2500	±	90